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UNIVERSITY OF ALBERTA

The Effects of Mechanical Site Preparation on
First Year Growth of Calamagrostis canadensis
and Other Vegetation in
Northern Alberta

BY

RODERICK W. NEGRAVE



A thesis submitted to the Faculty of Graduate Studies
and Research in partial fulfillment of the requirements
for the degree of MASTER OF SCIENCE.

DEPARTMENT OF FOREST SCIENCE

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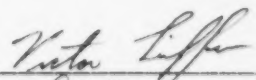
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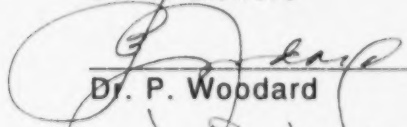
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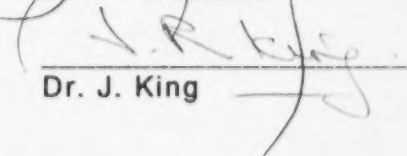
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Dr. V. Lieffers



Dr. P. Woodard



Dr. J. King

DEDICATION

I would like to dedicate this thesis to the late Mr. J. Stuart Hanna of Merritt, B.C. Mr. Hanna, a rancher, logger, and, above all, naturalist, was intimately familiar with forest and rangelands and the damage that human activities have on them. In the enlightened way he conducted his work in the forest, and by encouraging others to modify the way industrial and ranching activities were done, he sought to conserve the quality of the forests and grasslands that were his home. Mr. Hanna's philosophy on people, the landscape, and their interactions are a source of great inspiration to me. In dedicating this thesis to him, my only regret is that it is not a better piece of work.

ABSTRACT

In the boreal forest, the native grass Calamagrostis canadensis (Michx.)Beauv. (bluejoint) competes strongly with planted conifers on moist sites with mineral soils. Two experiments were initiated to examine the effects of different types of mechanical site preparation on the growth of bluejoint and associated vegetation. For both experiments, the following treatments were used: disk trenching, blading, ripper ploughing, and a non-treated control. In each treatment, specific microsites, where conifer seedlings are commonly planted, were chosen for investigation: in both the disk trench and ripper plough the hinge position was used; in the blade, an area with most or all of the LFH layer removed (scalp) was used; and in the control, an undisturbed location of medium elevation was used.

In the first experiment, bluejoint rhizomes were collected and planted into logged areas that had been treated with the above methods. The rhizomes were allowed to grow for one growing season and then dug up. From the sprouted rhizomes nine variables were examined; mass of sprouted rhizome, mass of shoots, number of rhizomes, number of shoots, maximum length of rhizome, average shoot height, total length of rhizome grown, number of rhizome growing tips, and number of ramets per plant. The blade and disk trench treatments had significantly more ramets per plant than the control or ripper plough treatments. For all the other variables the disk trench treatment had higher values than the other three treatments, which did not differ significantly. No significant differences were found for maximum rhizome length between treatments.

In the second trial, the cover, height, and frequency of bluejoint and other species were measured on permanently located plots on the above treated areas. Species were divided into those that increased in cover and vigour under mechanical site preparation, those that decreased, and those that were neutral. Species that increased were Populus tremuloides, Carex aenea, Equisetum arvense, and Polytricum commune. Species that were treatment neutral included Epilobium angustifolium and Rubus pubescens. Species that decreased in abundance and vigour were Aralia nudicaulis, Mitella nuda, Cornus canadensis, Petasites palmatus, Rosa acicularis, Mertensia paniculata, Rubus idaeus, Viburnum edule, Pleurozium schreberi, Ptilia crista-castrensis, and Calamagrostis canadensis. In the disk trench treatment, cover and heights of increaser species were greater than in the blade, ripper plough, and control treatments. The exception were decreaser species, which tended to have higher cover and height in the controls. No bluejoint germinants were observed, although rhizome penetration of disturbed soil was noted. It is cautioned that some of the species mentioned above are in a state of flux immediately following disturbance and long-term condition is not necessarily reflected by these results. Thus conclusions about long term conditions, or treatment advantage, based on this first year data would be premature.

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I thank the members of my committee for the time they have put into reviewing this thesis. I also thank my supervisor, Dr. V.J. Lieffers, for all the time he has put into the thesis and for the advice provided to me throughout my degree program. My good friend Sally Dailly provided much needed moral support, humour, and encouragement. I am also indebted to the B.C. Forest Service for providing material support in the preparation of this thesis. Finally, I thank my wife, Louise, who sacrificed much so that I could do this degree.

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1. Introduction.

One of the main reasons for the failure of white spruce, *Picea glauca* (Moench.) Voss, plantations on clearcuts in the boreal forest of northern Alberta is competition by bluejoint, *Calamagrostis canadensis* (Michx.) Beauv. This grass quickly invades logged areas (Drew 1988, Norokorpi 1986, Hogg and Lieffers 1991a, Hogg and Lieffers 1991b, Froning 1972) and competes with conifer seedlings, causing reduction in their growth and survival (Blackmore and Corns 1979, Norokorpi 1976, Froning 1972). Bluejoint invasion is especially severe on fertile, mesic to hygric sites with mineral soils that formerly supported growth of white spruce, *Picea glauca* (Moench.) Voss (Norokorpi 1986, Eis 1981, Powelson and Lieffers 1991b).

Mechanical site preparation has the potential to reduce competing vegetation on logged areas in some regions (McMinn and Hedin 1990, Drew 1988) and thus increase the chance of regeneration success of white spruce (Froning 1972, Drew 1988). However, it has been shown that mechanical site preparation does not always control competing vegetation on moist or wet sites in boreal and sub-boreal areas of western Canada (Hamilton and Yearsley 1988, Norokorpi 1988, MacKinnon and McMinn 1988, Haeussler *et al* 1990). Indeed, in some cases, soil disturbance has been shown to encourage colonization by bluejoint (Younkin 1974, Haeussler *et al* 1990, Hardy BBT Ltd. 1989).

Bluejoint invasion can prevent successful forest regeneration on logged areas (Norokorpi 1988). Unfortunately, there is conflicting information on how mechanical site preparation affects bluejoint encroachment. Given the considerable cost of site preparation, which generally must be carried through the entire rotation, there is a need to establish how site preparation affects bluejoint survival and growth.

SITE PREPARATION

Boreal Forest Soils in Alberta

Generally, boreal forest soils are, generally, moist, low in available nutrients, and quite cool (Pritchett and Fisher 1987). Approximately 400-500 mm of precipitation falls annually in northern Alberta (Norokorpi 1986). Although this is not a high level of precipitation, the evapotranspirational rate is not high, even in summer (Norokorpi 1986, Corns and Annas 1986). This moderate evapotranspiration and the slow drainage of fine textured soils found in most of the boreal forest in Alberta ensures that the soils are usually moist to wet (Norokorpi 1986).

Coniferous litter tends to decay very slowly due to high concentrations of insoluble or microbe inhibiting compounds, such as phenols and lignin, and low concentrations of soluble carbohydrates and nitrogen (McLaugherty *et al* 1985). Therefore, coniferous litter builds up on the forest floor of coniferous stands in the boreal forest as the stands age (Heiliman 1966, McLaugherty *et al* 1985). This build up of organic material insulates the soil from solar radiation and ensures that it remains relatively cool throughout the year (Heiliman 1985, Pritchett and Fisher 1987). The litter also reduces water evaporation from the soil surface (Pritchett and Fisher 1987).

A further effect of the build-up of litter and consequent insulating of the soil is a reduction in available soil nutrients (Heiliman 1966). As litter accumulates rather than decaying, increasing amounts of the site's available nutrients become unavailable to plant growth in the undecayed litter (Heiliman 1966, McLaugherty *et al* 1985). Reduced heat transfer into the soil means soils warm more slowly, which reduces time for microbial

action and thus inhibits litter decomposition, in addition to lowering the activity of mineral soil nitrogen (Heilman 1966).

An intact tree canopy reduces the incidence of summer frost in the understory by insulating the site and preventing excessive transmission of longwave radiation at night (Stathers 1989). When stands are logged, the removal of the protective tree canopy often leads to an increased occurrence of summer frosts (Stathers 1989). The presence of herbaceous, and especially grassy vegetation prevents turbulent mixing of air at the soil surface and makes the incidence and severity of summer frost worse. Herbaceous vegetation also lowers heat conduction from soil to air at night, which also increases the risk of frost. Thus smaller conifer seedlings, which are located at the same height as the top of the herbaceous layer are more likely to experience a summer frost (Stathers 1989).

The presence of bluejoint on a site can make low soil temperatures even more of a problem. Dead bluejoint litter is both light coloured and persistent. This light coloured litter has a high albedo, or ability to reflect incoming solar radiation, and further insulates soils on clearcuts (Hogg and Lieffers 1991b). These authors also showed that soils under bluejoint stands are colder than under stands of Epilobium angustifolium (L.), fireweed.

The Benefits of Mechanical Site Preparation

One aim of site preparation is to manipulate the soil surface to create microsites having improved growth conditions for seedlings and improved planter access (McMinn and Hedin 1990). A microsite can be defined as a small area of localized climate and soil conditions that exists within the more general conditions of the site (Orlander et al 1990). In practice, a microsite can be considered to be the area in which a single seedling would be planted. Using site preparation, the temperature, moisture, aeration, nutrient status, and physical properties of the soil can be modified along with competing vegetation, light

reaching the ground surface, incidence of frost, and pest damage (McMinn and Hedin 1990, Orlander *et al* 1990, Sims 1975). Of these conditions that have the potential to be modified, soil temperature and moisture status are the most affected by site preparation activities (Orlander *et al* 1990). This ability to raise soil temperature and modify soil moisture regimes is particularly important because, immediately after planting, seedlings have a reduced ability to take up water (Margolis and Brand 1990). This is due to damage sustained to their roots during lifting and planting and, sometimes, poor root to soil contact immediately after planting (Margolis and Brand 1990, Orlander *et al* 1990). Cold, water-saturated soils further increase water stress by making it more difficult for seedlings to absorb soil water (Grossnickle and Blake 1985, Grossnickle 1987) in addition to reducing root growth (Grossnickle 1987, Anderson *et al* 1986). In order for photosynthesis and thus growth to occur, the root systems of the newly planted seedlings must elongate and begin to take up water (Grossnickle and Blake 1985). By raising soil temperatures and reducing soil saturation, site preparation can enhance root activity and growth and thus maintain stomatal conductance and photosynthesis (Grossnickle and Blake 1985, Grossnickle 1987, Anderson *et al* 1986) and thus enhances seedling establishment. Warmer soil temperatures have also been shown to induce earlier spring bud growth (Sorensen and Campbell 1978).

Variations of Mechanical Site Preparation

Site preparation affects the soil environment by modifying the organic layers. Mechanical site preparation can be divided into several categories: scalping, mixing, inverting, and creating either raised or depressed microsites (McMinn and Hedin 1990).

Scalping involves scraping away organic material to expose the mineral soil. Organic matter acts as an insulator and reduces the warming of underlying mineral soil layers by

solar radiation. Removal of the organic layers allows mineral soil in the scalp to be directly exposed to solar radiation and thus heat up more during the day and reradiate more heat at night than if insulated by organic layers. Thus, not only is the rooting zone warmer in the daytime, but the reradiated heat decreases the risk of ground frost during the night (McMinn and Hedin 1990). However, the size of scalps must be large to reduce the incidence of ground frost (McMinn and Hedin 1990). Scalping is also thought to control competing vegetation by physically removing competing plants and any of their propagules that might be present in the organic layers (McMinn and Hedin 1990, Blackmore and Corns 1979) or by creating microsites with surfaces that are too harsh for germinating weed species to become established and thrive (MacKinnon and McMinn 1988). Common methods to create scalps include using a bulldozer or skidder with blade to scrape the forest floor and any slash off the mineral soil. Patch scarifiers, such as the Bracke scarifier, can be used to create small scalps. Disk trenchers, such as the Donaren 180T and 280T, create continuous scalped trenches (McMinn and Hedin 1990).

Mixing of organic material and mineral soil increase the rate of organic matter decomposition and nutrient availability by increasing the rate of soil warming and thus increasing the rate of microbial activity (McMinn and Hedin 1990). If mixing is intense, creating fine particles, it is reported to control competing vegetation by fragmenting roots and rhizomes and burying competing plants (McMinn and Hedin 1990). However, intense 30 cm deep mixing on a site in the boreal forest near Fort St. John, B.C., controlled bluejoint for only one year (P. Wadey as cited by Haeussler *et al* 1990, Coates *et al* 1990). Mixing of organic and mineral material can be accomplished by disk trenchers or ploughs that create berms of mixed material or with high speed mixers, such as the Madge Rotoclear (McMinn and Hedin 1990).

Inverting involves turning a piece of soil upside down so that the organic layers are touching and a mineral soil cap is left exposed on top of the organic layers. The benefits

of inverting include raised soil temperature via mineral soil exposure, as explained above, reduction of weed competition by burying propagules, and better access by the tree seedling's roots to nutrients at the mineral soil and forest floor interface in the cap (McMinn and Hedin 1990). Inverting is accomplished using backhoes, special mounding equipment or some types of ploughs (McMinn and Hedin, 1990).

The creation of raised or depressed microsites affects moisture relations and can also heat up the soil (McMinn and Hedin 1990, Orlander *et al* 1990). The creation of raised ridges or mounds allows these microsites to shed water and thus be drier, and also be warmer, compared to their surroundings. Conversely, depressions, such as trenches and holes, are moisture collection sites and are thus wetter, and cooler than their surroundings, due to the high specific heat of water (McMinn and Hedin 1990). Raised and depressed microsites are created by mounders, disk trenchers, and ploughs that leave berms (McMinn and Hedin, 1990). As previously mentioned, any warming of the soil via site preparation can also increase the available nutrients of a microsite. Nitrification rate increases with temperature (Tisdale *et al* 1985) and thus higher soil temperatures lead to higher nitrogen mineralization rates and increased nitrogen availability (Orlander *et al* 1990). However, any such increase in nutrients could increase the amount of competing vegetation, which will tie up these nutrients in weed biomass and make nutrients unavailable to the crop species (Orlander *et al* 1990).

BLUEJOINT ECOLOGY

Bluejoint is a widely distributed perennial grass species with a range from Greenland to Alaska and south to North Carolina and California (Hitchcock 1971). The culms on bluejoint are suberect and can have a maximum height of 60 to 150 cm (Hitchcock 1971). The inflorescence is a panicle that can be either broad and open or dense and narrow, is

slightly nodding, has one floret per spikelet, and is 10 to 25 cm long (Hitchcock 1971; Moss and Packer 1983). The leaf blades are numerous, elongate, flat, lax, scabrous, and 4 to 8 mm wide; the sheaths are glabrous or obscurely pubescent (Hitchcock 1971). The seed has a callus of numerous stiff hairs at its base (Moss and Packer 1983) which may aid in dispersal.

Bluejoint grows vigorously on burned, logged and recently cleared areas on mesic to moist sites in both the boreal and sub-boreal forests of western Canada and Alaska (Drew 1988, Eis 1981, Mitchell and Evans 1966, Viereck and Schandelmeier 1980). In the boreal forest, bluejoint rapidly colonizes areas disturbed by fire, often in association with fireweed (Lutz 1955, Ahlgren 1960). Light to moderate burns in particular are quickly colonized by bluejoint (Viereck and Schandelmeier 1980). Bluejoint is also found on areas disturbed by activities such as pipeline and seismic line construction in the western Arctic region of Canada (Younkin 1984). In both the boreal forest and western Arctic areas, bluejoint forms a minor component of the vegetation in non-disturbed, well drained areas (Younkin, 1974, Corns and Annas 1986). In the Arctic, bluejoint typically occurs as isolated, small, and chlorotic individuals in undisturbed areas. Usually, less than 5% of these individuals flower in any given year (Younkin 1974). In the western Arctic, bluejoint is found on all site types except wet depressions areas (Younkin 1974). In the boreal forest of western Canada, bluejoint grows sporadically under forest canopies, attaining average ground surface cover of about 3 to 5% in western Alberta (Corns and Annas 1986). Bluejoint may also be abundant in marshes and other very wet areas in the temperate and boreal regions where it can be very abundant (Hitchcock 1971).

Bluejoint reproduces both by seed and vegetatively by rhizomes (Younkin 1974, Moss and Packer 1983). Seed yields are low, 0 to 150 seeds per plant with a mean of 50, but seed viability in the western Arctic is very high, as much as 81% germination at 20°C down to 19% at 5°C (Younkin 1974). Germination decreased by 31% when seed was

germinated in the dark (Younkin 1974). Slight drought stress of -3 bars increased germination rates, however, water stress of -6 bars decreased germination, and recovery after the stress was poor (Younkin 1974). Germination of seed collected in the boreal forest of Alberta has been much lower at only 7 to 20% (Lieffers, personal communication, 1991). No germination occurs under severe drought conditions (Wein and Bliss 1973). Bluejoint seeds can survive, buried in the soil, for at least five years (Conn 1990).

Powelson and Lieffers (1991a) found that axillary rhizome buds generally remained dormant if the apex and plant base were left attached to rhizomes. Removal of either the rhizome apex or the base of the plant stimulated the sprouting of axillary buds (Powelson and Lieffers 1991a). Rhizome segments close to the apex are heavier and contain more non-structural carbohydrate (Powelson and Lieffers 1991a). Hogg and Lieffers (1991a) found that frequent defoliation reduces rhizome carbohydrate levels but in field sites shoot regrowth the following year was not affected by defoliation the previous year. They speculated that the reason for this was that defoliation removed litter and allowed the soil to warm, thus improving growth.

Bluejoint colonizes disturbed areas using both seed and residual rhizomes. On areas of exposed mineral soil in the western Arctic, where the rhizomes have been removed, colonization occurs via seed. The seed is dispersed into these disturbed areas in the late summer and early fall and overwinters before germinating the following spring. Areas of exposed mineral soil where bluejoint colonization is favoured are not excessively wet; they dry out for at least part of the growing season (Younkin 1974, Wein and MacLean 1973). Fireweed is often found growing with bluejoint in such areas (Wein and MacLean 1973). Once established in these areas, the growth of the bluejoint plants is very vigorous compared to its growth in undisturbed areas, up to 40-50 shoots are produced per clone and flowering increases to 30-50% (Younkin 1974). Disturbances thus provide an

opportunity for bluejoint populations to increase the amount of seed produced for recolonization. Once new plants are produced from seed, bluejoint expands vegetatively by means of rhizome growth (Younkin 1974).

In both the Arctic and the boreal forest, rhizomes can act as the primary colonizing agents when disturbance does not totally remove them from a site, such as when disturbance leaves some of the organic layers on the soil surface partially or wholly intact (Wein and MacLean 1973, Viereck and Schandelmeier 1980). Rhizomes have the ability to survive fires, except when fires are so severe that all the organic soil layers are removed (Lutz 1955, Ahlgren 1960), as the rhizomes mainly grow at the mineral-organic interface of the soil. Disturbances, such as winter logging, in the boreal forest that leave the forest floor largely intact and remove competing vegetation would offer ample opportunity for rhizomes to sprout and expand, forming new ramets, or individual members of the clone. In the case of winter logging, frozen soil and protection by snow prevents rutting and soil disturbance. Removal of the tree layer gives increased light intensity on the forest floor, which is lethal to many of the shade tolerant understory plants (Dyrness 1973). Bluejoint rhizomes can also grow into disturbed areas from adjacent, intact sods (Blackmore and Corns 1979).

Bluejoint responds strongly to overstory vegetation removal. Overstory removal acts as a stimulus for rhizome sprouting; dry matter tissue production by bluejoint increased by four times following fire in the western Arctic (Wein and Bliss 1973). Eis (1981) noted that following clearcut logging, bluejoint cover increased significantly on moist sites in the sub-boreal forests of British Columbia. Bluejoint went from a pre-logging cover of 20% and a height of 40 cm to a cover of 70-90% and a maximum height of 130 cm just three years after logging in the boreal forest of British Columbia (Haeussler *et al* 1990).

The role of seed as a colonizing agent of bluejoint in the boreal forest is uncertain. Ahlgren (1960) reported that wind disseminated seed is responsible for some bluejoint

reproduction on disturbed boreal sites but that vegetative reproduction was the dominant mechanism. However, Macdonald and Lieffers (1991) found large allozyme variation in bluejoint clones, growing on a logged area in northern Alberta, which indicates a probable seed origin of the clones.

Light disturbances, such as those described above may not always induce bluejoint colonization. Hernandez (1972) noted that in areas of the western Arctic where disturbance occurred in winter, with little mineral soil exposure, bluejoint was very scarce or absent altogether. This may be for several reasons: no mineral soil was exposed for seed germination and there were no bluejoint individuals present for rhizome growth to be stimulated; the disturbance was not severe enough to stimulate the bluejoint; any new growing space provided by the disturbance was occupied by other species; no bluejoint seed was present. Exposure of mineral soil, such as with mechanical site preparation, would also provide suitable sites for seed germination.

The effect of mechanical site preparation on the ability of bluejoint to colonize boreal clearcuts could be assessed by measuring the amount of mineral soil actually exposed by different mechanical site preparation methods; quantifying the ability of bluejoint rhizomes to survive and grow in areas of exposed mineral soil; and by measuring the degree to which bluejoint, and other species, occupy areas disturbed by mechanical site preparation.

The objectives of this thesis are as follows: to measure the growth of sprouts from bluejoint rhizomes in microsites created by disk trenching, ripper ploughing, and blading mechanical site preparation treatments plus a non-treated control; to measure the amount of mineral soil exposed by the above mentioned treatments; to describe, in terms of occurrence, cover, and height the growth of bluejoint and associated vegetation in the treatments described above in the first growing season following treatment.

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2. The Growth of Severed Calamagrostis canadensis in Microsites
Created by Different Mechanical Site Preparation Methods.

INTRODUCTION

Calamagrostis canadensis (Michx.)Beauv., or bluejoint, is a grass that is native to the boreal forest and arctic regions of western North America (Hitchcock 1971). Bluejoint grows in undisturbed areas of the boreal forest and arctic tundra, however, it is much more abundant and vigorous in the early seral stages after disturbances, such as logging or burning (Ahlgren 1960, Younkin 1974).

Bluejoint rapidly colonizes disturbed areas, such as seismic lines, in the arctic where it rapidly establishes a complete vegetative cover, thus reducing risk of soil erosion (Hernandez 1972, Younkin 1974). In the boreal forest of western Canada, bluejoint also quickly colonizes disturbed areas, notably areas that have been clearcut logged (Hogg and Lieffers 1991). On these boreal clearcuts, bluejoint colonization and subsequent luxuriant growth is one of the main factors leading to the failure of planted white spruce, Picea glauca (Moench.) Voss, plantations (Norokorpi 1988). The mechanism for bluejoint colonization of disturbances in the arctic is well documented (Hernandez 1972, Wein and Bliss 1973, Wein and MacLean 1973, Younkin 1974). Conversely, the mechanism by which bluejoint colonizes boreal clearcuts has not been clearly established. If performance of white spruce plantations in the boreal forest is to be enhanced, it must be determined how bluejoint invades logged areas. One way to do this is to examine reproductive mechanism of bluejoint.

Bluejoint can reproduce using both sprouts from rhizomes and seed (Moss and Packer 1983). In the arctic, bluejoint initially establishes by seed in areas where mineral soil has been exposed and rhizomes removed (Hernandez 1972, Younkin 1974). Once established by seed, the bluejoint expands further by rhizome production to infill any unoccupied space (Younkin 1974). Thus in the arctic, primary colonization is by seed and secondary expansion to infill unoccupied growing space is by rhizomes and their sprouts.

In the boreal forest, fire often leaves part or most of the forest floor intact and regeneration of bluejoint is mostly by sprouting from residual rhizomes, although seed accounts for some colonization (Ahlgren 1960, Lutz 1955). Blackmore and Corns (1979) noted that bluejoint occupies, by rhizome extension, small (28, 56 cm wide) scalps and areas where vegetation has been killed with herbicide. Haeussler *et al* (1991) noted that colonization of disturbed sites was first by rhizome extension and then by seed. Macdonald and Lieffers (1991) found large variation in allozymes taken from bluejoint clones on a mechanically site prepared clearcut in northern Alberta. The large variation in the allozymes indicates a probable seed origin of the clones. However, it has also been noted that bluejoint has very low seed yields (Younkin 1974) and that seed from northern Alberta has a very low germinability of between 7-20% on filter paper moistened with distilled water at 20 °C (V.J. Lieffers 1992, personal communication). Given the low seed germinability of bluejoint, and because mechanical site preparation (e.g. disk trenching) often leaves areas of the forest floor intact, the use of residual rhizomes as a primary colonizing agent on clearcuts should not be discarded. This is especially true as mechanical site preparation can fragment and spread intact rhizomes, thereby potentially increasing the number and distribution of propagules (V.J. Lieffers 1991, personal communication). Evidence as to whether rhizomes could actually survive and grow in the various mineral soil environments provided by different site preparation methods would contribute to our understanding of how bluejoint invades clearcuts in the boreal forest.

The objectives of this experiment were to examine the growth of bluejoint rhizomes planted in microsites created by a non-treated control and three types of mechanical site preparation; ripper ploughing, blading, and disk trenching, on clearcuts in northwestern Alberta. Variables examined include mass, number, and height of shoots; mass, number, and total length of rhizomes; length of longest rhizome; number of rhizome growing tips; and number of ramets.

METHODS AND MATERIALS

Study Sites.

Three sites were chosen for the experiment. The Judy Creek site was located approximately 40 km northwest of Whitecourt, Alberta, Canada ($54^{\circ} 25'$ north latitude, $116^{\circ} 50'$ west longitude). This site lies on a complex of orthic grey luvisols, derived from glacial till and shale, and mesisols derived from peat moss (Wynnyk *et al* 1969). The luvisols are moderately well drained while the organic soil is poorly drained. The Fox Creek site was located approximately 15 km southwest of Fox Creek, Alberta, Canada ($54^{\circ} 15'$ north latitude, $116^{\circ} 50'$ west longitude). The soils on this site were similar to those found at the Judy Creek site (Knapik and Lindsay 1983). The last site, near Ante Creek, was located approximately 56 km by road southwest of Little Smoky, Alberta, Canada ($54^{\circ} 30'$ north latitude, $117^{\circ} 30'$ west longitude). The soils at the Ante Creek site were a mix of the luvisols described above plus another moderately well drained luvisol of alluvial origin (Knapik and Lindsay 1983). Soil textures at all three sites were generally fine ranging from clay to loam, the most frequent texture being clay loam. Intact forest floor depths ranged from 7 to 24 cm. Elevation and orientation for the three sites were as follows. The Judy Creek site was about 1030 m in elevation and had a north-northwest orientation, Fox Creek was about 980 m in elevation with a north-northeast orientation, Ante Creek was about 880 m in elevation and had a southern orientation. All three sites are classified, according to Corns and Annas (1986) as transitional between the Lower Boreal Cordilleran White Spruce/ Viburnum/Rubus pubescens (LBC 4) and White Spruce/Viburnum/Aralia (LBC 5) ecosystem associations.

Methods

All three sites were clearcut logged using feller bunchers in the winter of 1989-90. Trees were grapple skidded to the roadside for processing. In the winter of 1990-91, four mechanical site preparation treatments (see Fig. 2.1) were applied, in random order, to uniform areas in each of the three study sites. These treatments included: 1) a non-treated control, 2) an area disk trenched using a Donaren 180T, 3) an area that was ripper ploughed using a D8 or D9 Caterpillar bulldozer, 4) and an area that was blade scarified to mineral soil, also with a large bulldozer. The disk trencher generally produced a shallow, 10-20 cm deep, trench which was cleared to mineral soil with a low ridge of mixed mineral and organic soil immediately to the side. The ripper plough produced a plough furrow in the mineral soil, which was up to 30 to 100 cm deep, with a ridge of mixed organic and mineral soil cast to the side. The bladed areas at Ante Creek and Fox Creek had deep scalps with the C horizon exposed in some areas. Some patches of A horizon mineral soil still remained. At Judy Creek the surface of the bladed area consisted of compacted peat with the surface vegetation scraped away. Each treatment was replicated once at each site.

On April 11, 1991, sods of bluejoint were dug up in the vicinity of the Judy Creek study site. The sods were stored at -2 °C until the third week of May, 1991. At this time the sods were broken apart and the bluejoint rhizomes extracted. The rhizomes were separated into segments containing either four or five nodes. Both the plant bases and the apical growing tips were removed from the rhizomes selected. Even though there were only four or five nodes per rhizome, some rhizomes were much longer than others. Rhizomes also varied in thickness. The four or five node segments were then randomly layered between wet peat in 5x30 cm germination trays and returned to -2 °C. The rhizomes were transported to the field, in moist peat at 0 °C, and planted at the study

sites. Ante Creek was planted in the third and Fox and Judy Creeks were planted in the fourth weeks of May. Rhizomes were planted in ten replicates of a microsites treatment at each site. The microsites in which the rhizomes were planted were those selected as the plantable microsites for the white spruce seedlings based upon the judgement of operational foresters. This was done because it would be in these areas, where the tree seedlings were planted, that the rhizomes would have to survive in order to compete the most with the trees. In the bladed areas, areas which appeared to have intact upper A horizons were used.

The microsites used were as follows (refer to Figure 2.1 for microsites used in the three mechanically treated areas). In the disk trenched areas, rhizomes were planted at the exposed interface of the mineral soil and the forest floor, i.e. the hinge point. The hinge point is thought to have the most desirable moisture and nutrient conditions for tree regeneration on mesic sites (McMinn and Hedin 1990). In the ripper ploughed areas, an area just below the hinge point was used as this would be more moist and not as prone to drought as the hinge point itself. In the bladed treatment, areas with some residual organic material left on top of the mineral soil were used as these areas would hold more moisture and nutrients. In the control treatment, patches of the forest floor were removed and the rhizomes placed directly on the mineral soil. These patches were then replaced over the rhizomes. This was done because bluejoint rhizomes were noted to grow along the interface between the forest floor and the mineral soil. Two rhizomes were planted at each microsite; each of these was randomly selected from the range of lengths and thicknesses noted above. Thus a total of twenty rhizomes were planted per treatment in each cutblock. As the treatments were replicated in three cutblocks, a total of 60 rhizomes were planted in each treatment for the whole experiment.

The rhizomes were allowed to grow until the end of September, 1991. On the 19-21 of September, after being allowed to grow all summer but before winter snows could hide

them, the rhizomes and their sprouts were dug up. The entire rhizome system, including above ground biomass, was placed in a paper bag and air dried for two months. Each rhizome system was then divided into aerial tissue, which included stems and leaves, and rhizomes. The original, planted rhizomes were separated from the rhizomes produced during the growing season and were not included in the analysis. Any root tissue still attached was removed and discarded. The number and lengths of stems and rhizomes was recorded. The total cumulative length of all rhizomes produced and the number of growing tips for the entire rhizome mass were also recorded. Additionally, the number of ramets, or individual clone members, which sprouted from each rhizome length was recorded for the Ante Creek and Judy Creek sites. The shoot and rhizome tissue was then dried at 70^o C for 72 hours and each component was weighed.

Statistical analysis was performed using the Statistical Analysis System (SAS). Analysis of variance was used to detect differences between treatments for the variables. A total of nine variables were analyzed. These variables were averages of the growth produced by each rhizome length and included: 1) new rhizome mass 2) shoot mass, 3) shoot numbers, 4) shoot height, 5) longest rhizome, 6) total rhizome length, 7) number of primary rhizomes, 8) number of rhizome growing tips, and 9) number of ramets. A nested analysis of variance design was used to detect differences in the variables due to treatment; each of the ten microsites per treatment was considered to be nested within the treatment. The variables from each group of two rhizomes were averaged on a microsite basis; if both planted rhizomes sprouted and produced growth, then each variable was taken as an average over both rhizomes. If only one rhizome sprouted in the microsite, then only these values were used. Microsites in which neither of the two rhizomes sprouted were treated as missing data points in the analysis. The SAS General Linear Model program (SAS Institute Inc. 1985), which was used to analyze the data, accounted for the missing data points in the analysis. Each of the three sites was regarded as a block

in the analysis. If the analysis of variance showed a significant treatment effect for a component, mean separation was then done using Scheffe's test (Steel and Torrie 1980, Ott 1984). The total number of rhizomes to survive and sprout in each treatment was also examined using a chi-squared test of independence. Separation of the number of rhizomes sprouting at each site was performed using a "Z" statistic (Ott 1984).

RESULTS

The chi-squared test of independence (Table 2.1) indicated that the number of rhizomes that sprouted was independent of treatment for all three sites combined. When the three sites were examined individually (Table 2.1), it was determined that at both the Judy and Fox Creek sites the numbers of rhizomes that sprouted were related to treatment type ($p < 0.05$). However, number of sprouting rhizomes and treatment type were independent at the Ante Creek site. To rank the treatments in terms of rhizome sprouting, further partitioning of numbers of rhizomes to sprout in each treatment at Judy and Fox Creeks was done using the "Z" statistic (Table 2.1) and showed the following. At Judy Creek, no difference in numbers of sprouted rhizomes existed among the blade, disk trench, and ripper plough treatments. No difference in sprouting existed between the disk trench and control treatments. Sprouting was significantly greater in the blade and ripper plough than in the control. At Fox Creek, greater numbers of rhizomes sprouted in the disk trench than in the other three treatments, among which no significant differences existed. In general, the numbers of rhizomes sprouted at Ante Creek was much lower than the other two sites and no rhizomes sprouted in the ripper plough treatment at Ante Creek.

Analysis of variance for new rhizome mass indicated that significant differences existed between treatments ($p < 0.1$, Table 2.2). No block (site) difference was noted. The mass of new rhizome tissue was found to be greater ($p < 0.05$) in the disk trench treatment (0.91

g per clone) than in the ripper plough (0.33 g), blade (0.37 g) and control (0.24 g) treatments, between which no differences were found (Table 2.3).

Significant differences in shoot mass were found between treatments ($p < 0.01$, Table 2.4). No block effect was noted. Shoot mass was higher ($p < 0.05$) in the disk trench treatment (2.21 g) than in the ripper plough (0.69 g), blade (0.79 g) and control (0.24 g) treatments, between which no significant differences were found to exist (Table 2.3).

Analysis of variance indicated that significant differences existed between the treatments for shoot height ($p < 0.05$, Table 2.2). No block effect was present. Shoot height was greatest ($p < 0.05$) in the disk trench treatment (19.26 cm), followed by the ripper plough (16.11 cm), and finally the blade (14.48 cm) and control (13.82 cm) treatments. No significant differences existed between the blade and control for stem height (Table 2.3).

Shoot number varied significantly with treatment ($p < 0.1$, Table 2.2). No block effect was found. Shoot numbers were greatest ($p < 0.05$) in the disk trench treatment (13.99) than in the ripper plough (6.91), blade (7.67) or control treatments (5.77), between which no significant differences existed (Table 2.3).

No significant differences were found among treatments for length of longest rhizome (Table 2.2). However, a significant block effect ($p < 0.1$) was found to exist. Rhizomes appeared to be longer at the Judy Creek site, particularly in the bladed treatment, than at either the Fox or Ante Creek sites (Table 2.3).

Rhizome numbers varied significantly among treatments ($p < 0.05$, Table 2.2). No block effect was found. No significant differences were found ($p < 0.05$) between the disk trench (6.06) and blade (4.00) treatments. However, the disk trench had significantly greater numbers of rhizomes than both the ripper plough (2.67) and the control (2.73) treatments (Table 2.3). No significant difference in rhizome numbers was found between the blade, ripper plough, and control treatments (Table 2.3).

Total length of new rhizomes also varied significantly ($p < 0.1$) with treatment (Table 2.2). No block effect was found. No significant difference in total rhizome length was found between the disk trench (119.58 cm) and blade (78.87 cm) treatments (Table 2.3). Total rhizome length was greater in the disk trench than in the ripper plough (51.87 cm) and control (44.80 cm) treatments. No differences existed between the blade, ripper plough, and control treatments for total rhizome length.

Number of rhizome growing tips differed significantly between treatments ($p < 0.1$, Table 2.2). No block effect was found. The disk trench had the largest ($p < 0.05$) number of growing tips (19.69) followed by the blade (11.37), control (8.41) and ripper plough (7.50) treatments, between which no significant differences existed.

Number of ramets per rhizome system was found to significantly differ among treatments ($p < 0.05$, Table 2.2). A significant block effect ($p < 0.1$) was also noted. Numbers of ramets appeared to be higher at Judy Creek than at the other two sites (Table 2.3). No significant difference in ramet numbers existed between the disk trench (2.44), blade (2.28), and ripper plough (1.50) treatments (Table 2.3). No differences were found between the blade and ripper plough treatments ($p < 0.05$) or between the ripper plough and control (1.10) treatments ($p < 0.05$). Both the disk trench and blade treatments had significantly more ramets than the control ($p < 0.05$).

DISCUSSION

This experiment indicates that bluejoint rhizomes can survive and grow in microsites created by mechanical site preparation. Bluejoint rhizomes generally produced the greatest growth on the disk trenched areas while blading, ripper ploughing, and non-treated controls produced the same degree of growth. Differences in growth between the

disk trench and the other treatments are likely due to the more favourable growing conditions provided by the disk trench microsite as a primary factor and possibly the reduction of bud dominance as a secondary factor. Given that rhizome growth tended to be greatest in the disk trenched areas, this treatment should not be used alone for the control of bluejoint on moister than average sites such as these.

Actual rhizome survival was quite low (0-70%) and was generally found to be independent of treatment. This low survival may have been due to low soil moisture (visually assessed) at the time of rhizome planting that would have caused desiccation and death of the rhizomes.

Of the three mechanical treatments used, the disk trenching treatment likely had the best growing conditions. Low impact mechanical site preparation, such as disk trenching, provides increased soil temperature (McMinn and Hedin 1990) and increased nutrient status compared to non-treated areas and areas where deep tillage is used (Van Cleve and Dyrness 1983, Orlander *et al* 1990). In contrast, high impact site preparation, such as ripper ploughing and deep blading, may cause too much soil temperature increase, with surface temperatures lethal to plants (Sims 1975). The removal to the LFH layers and the creation of high berms can also lead to large soil moisture deficits during the growing season (Sims 1975, McMinn and Hedin 1990). Removal of large amounts of the LFH layer and exposure of subsoil can also lead to low nutrient status (Sims *et al* 1984). Therefore, compared to the other three treatments, the disk trenched areas probably had better growing conditions, although this was not actually measured in this study but is being measured in a parallel study by Alcazar and Rothwell (unpublished data). However, it has been shown that disk trenching produces more vegetative growth within five years of treatment than higher impact treatments, such as various types of ploughing (L. Bedford, unpublished data).

Greater numbers of shoots, greater shoot height, and greater shoot mass produced in the disk trenched areas are indicative of higher soil nutrient regimes and generally improved growing conditions (Younkin 1974, Leakey *et al* 1978, Powelson and Lieffers 1991). The increased shoot growth would also have had an impact on rhizome growth.

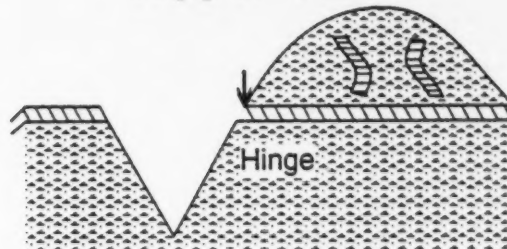
Once elevated out of the soil and photosynthesizing, a bluejoint shoot is basically independent of carbohydrate reserves in the rhizome and quickly reaches the time it begins to shunt carbohydrates back to the rhizomes (Hogg and Lieffers 1991). Thus the better growing conditions found in the disk trench would have led to greater rhizome growth there for two reasons, 1) more resources in the microsite for rhizome growth and 2) increased shoot, and thus photosynthetic tissue, leading to a higher production and storage of carbohydrate in the rhizomes.

Improved growing conditions, including greater resource availability, in the disk trenched areas may have resulted in less competition for resources among buds on the rhizomes. If there was less competition for resources, there may have been increased numbers of buds on the rhizome sprouting, which would have resulted in increased total growth of shoots and new rhizomes. This has been shown to be the case in studies on Agropyron repens (L.) where greater resource availability (i.e. more carbohydrates) leads to less dominance of the apical rhizome bud over other of the rhizome buds (Leakey *et al* 1978, McIntyre 1971 and 1970). Powelson and Lieffers (1991) found that, in severed bluejoint rhizomes, and to a lesser extent low carbohydrate segments of rhizome near the shoot base, some dominance was exerted by buds closest to the shoot base over buds located farther from the plant, along the rhizome. With A. repens, such dominance hierarchies can be relaxed and more sprouting can occur if nitrogen is highly available (McIntyre 1971). Such a reduction of dominance would account for the greater number of shoots, rhizome growing tips and greater number of rhizomes in the disk trenched

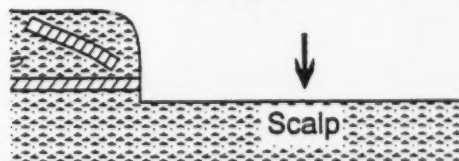
areas if these areas had faster mineralization rates and thus the greatest availability of nitrogen.

The implications of this study are that, given the greater bluejoint growth there, disk trenching by itself should not be used to control bluejoint. Disk trenching may be an appropriate site preparation treatment when combined with other vegetation control measures, such as herbicide application or grazing by domestic stock.

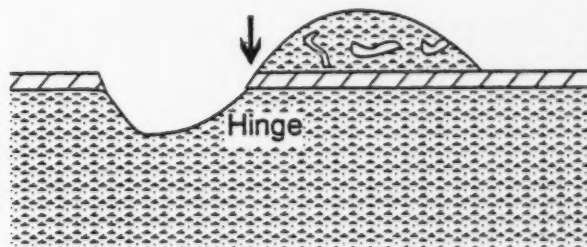
Ripper Plow



Blade



Disk Trench



Key

-  Mineral soil
-  Forest floor
-  Microsite used

Figure 2.1 Location of Microsites on Mechanical Treatments.

Table 2.1. Differences in Sprouting of Planted Rhizomes After One Growing Season.

Area		Number and Percent of Rhizomes Sprouted By Treatment				Chi-Square Significance Level
		Blade	Disk Trench	Ripper Plough	Control	
Judy Cr.	Number	12a	8ab	12a	4b	**
	%	60	40	60	20	
Fox Cr.	Number	7b	14a	6b	7b	**
	%	35	70	30	35	
Ante Cr.	Number	3a	3a	0a	2a	n.s.
	%	15	15	0	10	
Total	Number	22a	25a	18a	13a	n.s.
	%	37	42	30	22	

Note: n.s.= non-significant, * = 0.1 level, ** = 0.05 level, *** = 0.01 level. Identical letters in the same row indicate no significant differences ($p < 0.05$) as given by a "Z" test.

Table 2.2 Analysis of Variance for Growth of Planted Rhizomes in Mechanically Prepared Sites in Northwestern Alberta

Variable	Source	Df	SS	MS	Test F	P	Significance
New Rhizome Mass	Block	2	0.841	0.656	0.641	0.538	NS
	Treatment	3	2.647	0.882	2.282	0.091	*
	Subplot Error	47	18.105	0.387			
Shoot Tissue Mass	Block	2	2.696	1.348	0.696	0.511	NS
	Treatment	3	17.185	5.728	4.569	0.007	***
	Subplot Error	44	54.873	1.253			
Shoot Height	Block	2	57.285	28.642	1.136	0.34	NS
	Treatment	3	214.567	71.522	3.921	0.015	**
	Subplot Error	41	740.601	18.241			
Total Shoot Number	Block	2	300.214	150.107	1.985	0.162	NS
	Treatment	3	470.418	150.806	2.703	0.058	*
	Subplot Error	40	2316.38	58.011			
Longest Rhizome	Block	2	828.046	414.523	3.363	0.054	*
	Treatment	3	315.571	105.19	0.939	0.432	NS
	Subplot Error	38	4278.25	112.084			
Total Rhizome Number	Block	2	59.165	29.583	2.013	0.1585	NS
	Treatment	3	111.89	37.297	3.1	0.038	**
	Subplot Error	39	472.015	12.032			
Total Rhizome Length	Block	2	45362.9	22681.5	1.882	0.177	NS
	Treatment	3	44091.5	14673.2	2.242	0.0966	*
	Subplot Error	44	290041	6545.71			
Total Growing Tip Number	Block	2	373.63	186.815	1.405	0.268	NS
	Treatment	3	1095.98	361.992	3.939	0.015	**
	Subplot Error	41	3781.87	91.905			
Total Ramet Number	Block	1	5.281	5.281	8.593	0.061	*
	Treatment	3	10.153	3.384	3.911	0.021	**
	Subplot Error	24	21.105	0.865			

Note: Significance level is indicated by * for 0.1; ** for 0.05; *** for 0.01; and NS for not significant. Block is a test for differences among the sites. Treatments are listed in Table 2.3.

Table 2.3 Growth of Planted Rhizomes on Mechanically Site Prepared Areas in Northwestern Alberta (Mean and Standard Error)

Variable	Treatment	Means and Standard Errors by Location			
		Judy Creek	Fox Creek	Ante Creek	Combined
		Mean, SE	Mean, SE	Mean, SE	Mean, SE
New Rhizome Mass (g)	Disk Trench	0.70, 0.21	1.22, 0.44	0.80, -	0.91a, 0.24
	Ripper Plough	0.30, 0.08	0.70, 0.21	*	0.33b, 0.10
	Blade	0.56, 0.24	0.34, 0.21	0.07, 0.01	0.37b, 0.14
	Control	0.24, 0.11	0.36, 0.07	0.61, 0.53	0.24b, 0.06
Shoot Mass (g)	Disk Trench	2.06, 0.49	0.82, 0.96	3.97, 2.05	2.21a, 0.46
	Ripper Plough	0.81, 0.15	0.80, 0.26	*	0.69b, 0.13
	Blade	1.20, 0.32	0.40, 0.05	0.30, 0.00	0.79b, 0.18
	Control	0.30, 0.00	0.66, 0.11	0.30, 0.00	0.60b, 0.12
Shoot Height (cm)	Disk Trench	18.60, 1.91	19.79, 1.53	17.70, 1.12	19.26a, 1.07
	Ripper Plough	17.00, 0.89	16.06, 2.19	*	16.11b, 1.05
	Blade	15.35, 1.71	14.25, 2.19	8.70, 0.64	14.48bc, 1.32
	Control	16.90, 4.85	14.48, 1.43	7.20, 0.50	13.82c, 1.71
Total Shoot Number	Disk Trench	12.50, 3.05	10.00, 1.71	27.33, 14.53	13.99a, 2.82
	Ripper Plough	7.86, 1.68	5.60, 1.29	*	6.91b, 1.12
	Blade	13.57, 3.28	2.50, 0.22	2.50, 0.50	7.67b, 2.08
	Control	6.33, 1.45	5.92, 0.71	4.50, 1.50	5.77b, 0.58
Total Rhizome Number	Disk Trench	5.33, 1.26	6.00, 1.09	7.67, 4.41	6.06a, 0.92
	Ripper Plough	3.64, 0.82	1.30, 0.58	*	2.67b, 0.63
	Blade	6.86, 2.28	2.08, 0.66	2.00, 1.00	4.00ab, 1.25
	Control	4.17, 2.32	2.42, 0.52	1.00, 0.00	2.73b, 0.67
Longest Rhizome (cm)	Disk Trench	24.00, 3.95	19.86, 3.94	20.93, 4.30	21.47a, 2.40
	Ripper Plough	24.63, 4.06	7.20, 4.40	*	17.37a, 3.56
	Blade	23.66, 4.14	10.55, 4.58	9.10, 2.70	15.63a, 3.18
	Control	20.13, 6.77	18.62, 3.95	4.35, 1.15	16.44a, 3.18
Total New Rhizome Length (cm)	Disk Trench	117.38, 21.59	119.27, 21.59	124.93, 84.19	119.58a, 23.83
	Ripper Plough	72.97, 17.09	22.32, 12.63	*	51.87b, 13.18
	Blade	151.03, 62.60	27.00, 12.72	14.10, 5.90	78.87ab, 33.49
	Control	62.77, 38.20	49.30, 13.04	4.35, 1.15	44.80b, 12.87
Total Number of Growing Tips	Disk Trench	20.00, 3.51	18.56, 4.15	24.67, 11.57	19.69a, 2.73
	Ripper Plough	8.36, 2.01	6.30, 2.95	*	7.50b, 1.64
	Blade	19.21, 6.24	6.58, 1.37	1.00, 0.00	11.37b, 3.48
	Control	11.5, 4.31	9.33, 2.50	1.50, 0.50	8.41b, 2.01
Total Ramet Number	Disk Trench	2.50, 0.34	*	2.33, 0.88	2.44a, 0.34
	Ripper Plough	1.50, 0.15	*	*	1.50a, 0.15
	Blade	3.36, 0.59	*	1.00, 0.00	2.28abc, 0.44
	Control	1.17, 0.17	*	1.00, 0.00	1.10c, 0.10

Note: Identical letters in the same column indicate no significant differences ($p < 0.05$) as given by Scheffe's test.

Asterisk (*) indicates missing data.

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3. The Effects of Mechanical Site Preparation on the First Year
Colonization of Calamagrostis canadensis and Other Plant Species.

INTRODUCTION

Mechanical site preparation is used extensively in forestry to enhance the survival and growth of conifer plantations (Smith 1986). Benefits of mechanical site preparation can include an increase in soil temperatures due to removal of insulating forest floor material (Sims 1975); increased soil aeration, improved soil moisture regime, better planter access; reduction of summer frost; and possibly increased fertility due to enhanced organic matter decomposition (McMinn and Hedin 1990, Orlander *et al* 1990).

The effects of mechanical site preparation on competing vegetation are inconsistent. Mechanical site preparation does have the potential to reduce competition against crop trees by removing propagules, which lie in the top soil strata, and by creating conditions unsuitable for germination and growth of competitor species (McMinn and Hedin 1990). However, by exposing mineral soil, the risk of competitor establishment may increase because many species require exposed mineral soil to germinate (Bell 1991). Presumably, enhancement of growing conditions for crop trees, also enhances growing conditions for competitors, which rely on the same resources as the crop. Certainly in the western Canadian boreal and sub-boreal forests mechanical site preparation has failed to prevent early seral vegetation from dominating clearcuts, particularly the native grass *Calamagrostis canadensis* (Michx.) Beauv., or bluejoint (Bell 1991, Hamilton and Yearsley 1988). Further quantification of the effects of mechanical site preparation on the colonization and growth of competing vegetation, particularly bluejoint, will aid in determining the best mechanical site preparation procedures.

Clearcutting and soil disturbance create early seral conditions (Kimmins, 1987). These conditions are characterized by an increase in light reaching the forest floor; increases in soil temperature and soil temperature fluctuations; increased mineralization and thus

availability of mineral nutrients; increased fluctuations in soil wetting and drying cycles (Boring and Monk 1981, Kimmins 1987). The increased light intensities and soil disturbance cause a decline in the abundance and vigour of shade tolerant, residual understory species and an increase in shade intolerant, early seral species. As time progresses from the disturbance, and canopy closure increases, the understory species begin to increase in abundance and the amount of shade intolerant early seral vegetation decreases (Dyrness 1973).

In the boreal and sub-boreal forest of western Canada, this progression is from herbaceous to increasingly shrub dominated communities (Eis 1981, Hamilton and Yearsely 1988, Norokorpi 1986). On moist, mineral soil sites in the sub boreal and especially in the boreal forest, the herbaceous community is dominated by bluejoint or Epilobium angustifolium L., fireweed (Eis 1981, Hamilton and Yearsely 1988, Norokorpi, 1986). This herbaceous community peaks in cover and vigour about four to ten years after disturbance (Eis 1981, Hamilton and Yearsely 1988, Norokorpi 1986). After this time, shrubs increasingly dominate the site and shade out the herbaceous plants until an overstory of tall shrubs and deciduous trees is established (Norokorpi 1986).

Very few studies document the effect of mechanical site preparation on competing vegetation in the boreal and sub boreal areas. MacKinnon and McMinn (1988) noted that severe treatments, blading and breaking plough, gave good vegetation control but that conifer seedling growth was very poor. Disk trenching was a less severe treatment but gave poor vegetation control (MacKinnon and McMinn 1988). Norokorpi (1986) noted that mechanically treated areas, especially water receiving depressions, had high bluejoint cover. Haeussler et al (1990) stated that intense, 30 cm deep roto-tilling controlled bluejoint for only one year. Eis (1981) found that bluejoint quickly occupied areas of exposed mineral soil, such as skid trails and roads, on logged areas. The objectives of this experiment are to compare three methods of mechanical site preparation, disk trenching,

blading, and ripper ploughing, with a non-treated control, in order to assess differences in the amount of mineral soil exposed and the presence, cover and vigour of bluejoint and any other abundant plant species.

METHODS AND MATERIALS

Study Sites.

Three sites were chosen for the experiment. The Judy Creek site was located approximately 40 km northwest of Whitecourt, Alberta, Canada (54° 25' north latitude, 116° 50' west longitude). This site lies on a complex of orthic grey luvisols, derived from glacial till and shale, and mesisols derived from peat moss (Wynnyk *et al* 1969). The luvisols are moderately well drained while the organic soil is poorly drained. The Fox Creek site was located approximately 15 km southwest of Fox Creek, Alberta, Canada (54° 15' north latitude, 116° 50' west longitude). The soils on this site were similar to those found at the Judy Creek site (Knapik and Lindsay 1983). The last site, near Ante Creek, was located approximately 56 km by road southwest of Little Smoky, Alberta, Canada (54° 30' north latitude, 117° 30' west longitude). The soils at the Ante Creek site were a mix of the luvisols described above plus another moderately well drained luvisol of alluvial origin (Knapik and Lindsay 1983). Soil textures at all three sites were generally fine ranging from clay to loam, the most frequent texture being clay loam. Intact forest floor depths ranged from 7 to 24 cm. Elevation and orientation for the three sites were as follows. The Judy Creek site was about 1030 m in elevation and had a north-northwest orientation, Fox Creek was about 980 m in elevation with a north-northeast orientation, Ante Creek was about 880 m in elevation and had a southern orientation. All three sites are classified, according to Corns and Annas (1986) as transitional between the Lower

Boreal Cordilleran White Spruce/ Viburnum/Rubus pubescens (LBC 4) and White Spruce/Viburnum/Aralia (LBC 5) ecosystem associations.

Methods

All three sites were clearcut logged using feller bunchers in the winter of 1989-90. Trees were grapple skidded to the roadside for processing, following felling. In the winter of 1990-91, four mechanical site preparation treatments (Fig. 3.1) were applied, in random order, to uniform areas in each of the three study sites. These treatments included: 1) a non-treated control, 2) an area disk trenched using a Donaren 180T, 3) an area that was ripper ploughed with a D8 or D9 Caterpillar bulldozer, 4) and an area that was scarified to mineral soil, also using a large bulldozer. The disk trencher produced a shallow, 10-20 cm deep, trench which was cleared to mineral soil with a low ridge of mixed mineral and organic soil immediately to the side. The ripper plough produced a furrow 30 to 100 cm deep in the mineral soil with a ridge of mixed organic and mineral soil cast to the side. The bladed areas at Ante Creek and Fox Creek were deep scalps with the C horizon breaking through in some areas. Some patches of residual organic stained mineral soil remained. At Judy Creek, the blade was much less severe and consisted of lightly scalped mineral soil with large patches of residual forest floor. These forest floor patches had most of the loose organic material removed. Each treatment was replicated once at each site.

A 30x30 cm metal frame was used to assist in the visual estimation of cover. The frame was mounted on 20 cm pins in each corner, so that the frame could be positioned horizontally over individual microsites. This was done by inserting the pins in the ground such that the frame was suspended over the microsite. On sloping ground, the pins were inserted to different depths. This allowed the frame to remain at the same horizontal

angle, even if the slope of the ground changed. This 30 x 30 cm size were used to approximate an area of immediate influence experienced by a single planted conifer seedling. This was done because it would be in these areas that the seedlings would most immediately have to compete with encroaching vegetation. The microsites used were as follows (refer to Figure 3.1). In the disk trenched areas, the exposed interface of the mineral soil and the forest floor, the hinge point, was used. The hinge point is thought to have the most desirable moisture and nutrient conditions for tree regeneration on mesic sites (McMinn and Hedin 1990). In the ripper ploughed areas, an area just below the hinge point was used as this would be more moist and not as prone to drought as the hinge point itself. In the bladed treatment, areas that had most or all of the LFH layer removed were used. These three microsite types were typically the areas chosen by operational planters. In the control treatment, areas that did not have standing water at the soil surface in early June or excessive accumulations of slash and that seemed representative of the area were used.

Forty 30 x 30 cm quadrats (same size as the frame mentioned above) were located per treatment, in the microsites described above, on each of the three blocks. Thus a total of 120 quadrats per treatment were examined across the entire experiment. In each treatment area, the quadrats were located on 20 m transects; there were five quadrats per transect. Each of the five quadrats was located on the transect using a random number table. A painted metal pin was placed at each quadrat location to permanently mark its location for positioning of the metal frame.

In early June of 1991, each quadrat was inspected and the cover of exposed mineral soil determined. The cover was estimated visually within the frame described above. Mineral soil was defined as areas of exposed mineral horizons free of a contiguous cover of organic litter, slash, moss beds or peat.

In August of 1991, data on twenty plant species in the quadrats were collected. The presence only of the following eleven species was noted; Rubus pubescens Raf. (dewberry), Populus spp.(includes both Populus tremuloides Michx. (aspen) and Populus balsamifera balsamifera L.(balsam poplar)), Rosa acicularis Lindl.(prickly rose), Petasites palmatus (Ait.)A. Gray.(palmate-leaved coltsfoot), Cornus canadensis L.(bunchberry), Mitella nuda L.(mitrewort), Pleurozium schreberi, Ptilia crista-castrensis, and Polytricum commune. Only the presence of these species was noted because they were not very common or generally abundant on the three sites. In addition to having their presence noted, the other nine species also had their cover and mean height recorded. These nine species appeared to be the most abundant species on some or all of the sites and included species that were known to compete with conifer seedlings. These species include; Calamagrostis canadensis (Michx.)Beauv. (bluejoint), Epilobium angustifolium L. (fireweed), Mertensia paniculata (Ait.)G. Don. (tall mertensia), Rubus idaeus L.(red raspberry), Aralia nudicaulis L.(wild sarsaparilla), Carex aenea Fern., Equisetum arvense L.(horsetail), Populus tremuloides Michx., and Viburnum edule (Michx.)Raf. (mooseberry). Absolute cover was defined as that area of the ground covered by the species when the quadrat was observed vertically from above. For recording plant cover, species were divided into woody, herbaceous, and moss layers. The cumulative cover for all species occurring in a layer did not exceed 100%. Layers were used for assessing cover because of the overtopping that occurs among woody plants and herbaceous plants and mosses. Mean height of a species in a quadrat was determined by choosing a plant of average height for that species and measuring the height of it. In measuring the height of the vegetation, any drooping leaves, such as were found with bluejoint, were extended for the measurement. Due to the difficulty of distinguishing between small seedlings of Populus tremuloides and Populus balsamifera balsamifera, cover and height was only recorded if the seedlings could be positively identified, otherwise Populus spp. presence

only was noted. Species identification and classification was by Moss and Packer (1983) and Vitt *et al* (1988).

Statistical analysis was done using the Statistical Analysis System (SAS Institute Inc. 1985). Tests used were the chi-squared test of independence (Ott 1984) to detect differences in species occurrence between the treatments and analysis of variance to detect differences in cover and species height between the treatments. A nested design was used in the analysis of variance where the transects were considered nested within each treatment area. The three sites were designated as blocks in the analysis. If a species did not occur on a site, then the block was removed from the analysis of variance for that species. This decreased the degrees of freedom for block by one for each site the species did not occur on. For example, aspen was only found on two sites. This decreased the degrees of freedom for block from 2 to 1. However, the loss of one degree of freedom in the block did not affect the degrees of freedom of the subplot error, used as the denominator in the testing for treatment effects and quoted in the accompanying tables. In the case of mooseberry, which was only found at Judy Creek, a randomized block anova was used to detect treatment differences. Numerical values of cover and plant height for each transect were determined by averaging the values for the five quadrats that comprised each transect. The chi-squared tests were conducted using presence in individual quadrats, rather than using transect averages. Given significant chi-squared values, treatments were separated, in terms of species occurrence, using a Z-test (Ott 1984). Given a significant F-test in the analysis of variance, mean separation for the treatments was conducted using Scheffe's test with a 95% level of significance (Steel and Torrie 1980).

RESULTS

Mineral soil cover in the microsites examined was 83.4 % in the bladed treatment, 77.3% in the ripper plough treatment, 63.2 % in the disk trench, and 4.9 % in the control (Table 3.1). Significant differences in mineral soil exposure existed among the treatments at the 99 % confidence level (Table 3.3). The control had less mineral soil exposure than the other three treatments (Table 3.1). The blade had more exposure than either the disk trench or the ripper plough, and the ripper plough had more than the disk trench.

Bluejoint had a mean cover of 21.5 % in the control, 3.7 % in the disk trench, 1.9 % in the ripper plough, and 0.7 % in the blade (Table 3.1). Significant differences existed in bluejoint cover between the treatments (99 %level, Table 3.3). The control was found to have higher bluejoint cover than the other treatments, which did not differ significantly from each other. Mean bluejoint height was 38.8 cm in the control, 19.6 cm in the disk trench, 12.2 cm in the blade, and 11.6 cm in the ripper plough area (Table 3.2). Height was significantly different among the treatments at the 99 % level of confidence (Table 3.4). The control had taller bluejoint plants than the other three treatments. No significant differences in bluejoint height existed among the other three treatments (Table 3.2). In terms of occurrence, bluejoint had a higher frequency in the control than the disk trench; the disk trench higher than the blade or ripper plough; while the blade and ripper plough did not differ significantly from each other (Table 3.5).

Carex aenea had an average cover of 6.6 % in the disk trench, 5.5 % in the ripper plough, 2.7 % in the blade, and 1.8 % in the control (Table 3.1). Differences in cover were significant at the 99 % level of confidence (Table 3.3). The control and blade treatments had less Carex aenea cover than the disk trench and ripper plough treatments. No differences in cover existed between either the blade and the control or between the disk trench and the ripper plough (Table 3.1). Occurrence of Carex aenea was highest in

the disk trench followed by the ripper plough, blade and control (95% level Table 3.5). Carex aenea height was 19.3 cm in the disk trench, 11.9 cm in the ripper plough, 8.4 cm in the blade, and 5.5 cm in the control (Table 3.1). Differences in height were significant at the 99 % level (Table 3.4). Carex aenea height was lowest in the control and blade treatments, between which no differences existed, and highest in the disk trench, followed by the control (Table 3.2).

Epilobium angustifolium, fireweed, cover was 1.7 % in the control, 1.3 % in the disk trench, 1.3 % in the ripper plough, and 0.5 % in the blade (Table 3.1). No significant differences existed in fireweed cover between the treatments (Table 3.3). Neither was there any differences in fireweed occurrence (Table 3.5). Fireweed height was 7.8 cm in the control, 6.8 cm in the disk trench, 6.5 cm in the ripper plough, and 3.1 cm in the blade. No differences in height existed between the treatments (Table 3.4).

Equisetum arvense, horsetail, had an average cover of 2.5 % in the disk trench, 1.6 % in the ripper plough, 1.1 in the control, and 0.6 % in the blade (Table 3.1). Significant differences in cover existed at the 95% level (Table 3.3). No differences in cover existed between the disk trench and ripper plough treatments (Table 3.1). No differences in cover existed between the ripper plough, blade and control treatments (Table 3.1). Horsetail occurrence was highest in the disk trench and ripper plough, between which no differences existed (95%, Table 3.5). No difference in occurrence existed between the control and blade (95% level, Table 3.5). Horsetail height was 8.0 cm in the ripper plough, 7.5 cm in the disk trench, 7.9 in the control, and 3.4 cm in the blade. No significant differences existed for height (Table 3.4).

Mertensia paniculata, tall mertensia, had an average cover of 6.9 % in the control, 2.5 % in the ripper plough, 1.1 % in the blade, and 0.6 % in the disk trench (Table 3.1). Cover differed significantly at the 99 % level (Table 3.3). The control had a higher cover of tall mertensia than the other three treatments, which did not differ. The control had

higher tall *mertensia* occurrence than the other three treatments(95%), which did not differ in occurrence. Tall *mertensia* height was 15.0 cm in the control, 7.9 cm in the blade, 7.4 cm in the ripper plough, and 1.9 cm in the disk trench. Height differed significantly among treatments at the 95% level(Table 3.2). Tall *mertensia* was higher in the control than in the other treatments, which did not differ significantly (Table 3.2).

Rubus idaeus, red raspberry, cover was 4.0 % in the control, 1.5 in the disk trench, 1.1 in the blade, and 1.1 in the ripper plough (Table 3.1). Raspberry cover differed significantly between treatments (99% level, Table 3.3). The control had significantly higher cover than the other treatments (Table 3.1), which did not differ. The control and disk trench had the highest raspberry occurrence followed by the ripper plough and the blade (95% level, Table 3.5). Raspberry height was 20.0 cm in the control, 5.5 in the blade, 4.3 in the ripper plough, and 4.0 in the disk trench. No significant differences in height existed (Table 3.4). Most of the raspberry consisted of first year canes, although older canes appeared to be more common in the control.

Populus tremuloides, aspen, had covers of 2.8 % in the control, 1.8 in the disk trench, 0.8 in the ripper plough, and 0.9 in the blade (Table 3.1). Cover did not differ significantly between treatments (Table 3.3). *Populus* spp. occurrence, which included both aspen and *Populus balsamifera balsamifera* did not differ between the disk trench and the blade (95%, Table 3.5). Nor did occurrence differ between the ripper plough and the blade; the control had the lowest occurrence (95%, Table 3.5). Aspen heights were 21.9 cm in the control, 10.8 in the disk trench, 5.0 in the ripper plough, and 4.9 in the blade. Aspen height differed significantly between treatments at the 90 % level (Table 3.4). No differences in height existed between the disk trench and control treatments (Table 3.2). No differences in height existed between the disk trench, ripper plough, and blade treatments (Table 3.2). *Populus* seedlings appeared to be more common in the ripper plough and blade than in the disk trench and control, although some seedlings were found in the disk trenched areas.

Aspen suckers were much more common in the disk trench and control treatments than in the ripper plough and blade treatments.

Aralia nudicaulis, wild sarsaparilla, had covers of 6.0 % in the control, 1.9 % in the ripper plough, 0.4 % in the blade, and 0.4 % in the disk trench (Table 3.1). Cover differed significantly at the 99 % level (Table 3.3). The control had higher cover than the other treatments (Table 3.1), which did not differ significantly. Wild sarsaparilla frequency was highest in the control, followed by the disk trench and ripper, which did not differ; frequency was lowest in the blade (95%, Table 3.5). Heights were 12.2 cm in the control, 6.4 in the ripper plough, 5.1 in the blade, and 3.8 in the disk trench. Height of wild sarsaparilla was significantly greater in the control than the other treatments (95 %, Table 3.4; 95% Table 3.2), which did not differ significantly.

Viburnum edule, mooseberry, had covers of 5.2 in the control, 0.7 in the ripper plough, 0.8 in the blade, and 0.6 in the disk trench (Table 3.1). Mooseberry cover was significantly higher in the control than in the other treatments (99 %, Table 3.3; Table 3.1), which did not differ. Mooseberry frequency was higher in the control than in the other treatments (95%, Table 3.5). No difference in frequency existed between the disk trench and ripper plough; the blade had the lowest frequency (95%, Table II.5). Mooseberry heights were 20.4 cm in the control, 6.6 in the ripper plough, 6.0 in the disk trench, and 4.5 in the blade. Mooseberry was significantly taller in the control than in the other treatments (99%, Table 3.4; Table 3.1), which did not differ.

Occurrence of Pleurozium schreberi, was greatest in the control and least in the blade; the disk trench and ripper plough did not differ (95%, Table 3.5). For Ptilia crista-castrensis, no difference in occurrence existed between the control and the disk trench, which had the highest frequency, followed by the ripper plough (95%, Table 3.5). No difference in occurrence existed between the ripper plough and the blade (95%, Table 3.5). For Polytricum commune, frequency was highest in the disk trench followed by the

control, the ripper plough, and the blade (95 %, Table 3.5). The Pleurozium schreberi and Prilia crista-castrensis appeared to be more healthy in slightly shaded environments, which tended to be more common in the control and disk trench treatments.

Occurrence of Rosa acicularis, wild rose, was highest in the control and disk trench treatments, which did not differ; disk trench occurrence did not differ from ripper plough; neither did the blade and the ripper plough differ (95%, Table 3.5).

Petasites palmatus, palmate-leaved coltsfoot, occurrence in the control and disk trench treatments did not differ; both the control and disk trench treatments had higher frequencies than the blade and ripper plough treatments , which did not differ (95%, Table 3.5).

Cornus canadensis, bunchberry, frequency was highest in the control followed by disk trench. Lowest were the ripper plough and blade, which did not differ (95%, Table 3.5).

Occurrence of Mitella nuda, mitrewort, was highest in the control ; no differences existed between the disk trench, the ripper plough, and the blade (95%, Table 3.5).

The occurrence of Rubus pubescens, dewberry, did not vary between the treatments (Table 3.5).

DISCUSSION

The species examined can be divided into three groups in terms of their response to mechanical site preparation; species that increased their cover and vigour (increasers), species that decreased their cover and vigour (decreasers), and species that neither increased or decreased in cover and vigour (neutral species). Species response to the various treatments can be explained in terms of microsite differences, establishment requirements of the species, and reproductive methods used by the species.

Microsite Differences

Of the three mechanical treatments used, the disk trenching treatment likely had the best growing conditions. Low impact mechanical site preparation, such as disk trenching, provides increased soil temperature (McMinn and Hedin 1990) and increased nutrient status compared to non-treated areas and areas where deep tillage is used (Van Cleve and Dyrness 1983, Orlander *et al* 1990). In contrast, high impact site preparation, such as ripper ploughing and deep blading, can perhaps increase soil temperatures too much; temperature levels lethal to plants were recorded on ploughing treatments in Manitoba (Sims 1975). The removal to the LFH layers and the creation of high berms can also lead to large soil moisture deficits during the growing season (Sims 1975, McMinn and Hedin 1990). Removal of large amounts of the LFH layer and exposure of subsoil can also lead to low nutrient status (Sims *et al* 1984). Therefore, compared to the other three treatments, the disk trenched areas probably had better growing conditions, although this was not actually measured. However, it has been shown that disk trenching produces more vegetative growth within five years of treatment than higher impact treatments, such as various types of ploughing (L. Bedford, unpublished data).

Progressively more mineral soil was exposed in the disk trench, ripper plough, and blade treatments (Table 3.1). Greater mineral soil exposure gave greater opportunity for establishment of those species that require mineral soil for seed germination and plant establishment.

Increaser Species

The increasing species were Carex aenea, Equisetum arvense, Populus tremuloides, and Polytricum commune. All four of these species generally increased in cover and height as a result of some mechanical site preparation. Both height and cover tended to be greatest

in the disk trench treatment followed by the ripper plough. This was likely due to improved growing conditions found in the disk trench microsites. In some cases, Polytricum commune, for example, the greatest response was on the disk trench followed by the control. This indicates that, although these are colonizing species, they tend to be favoured on lighter disturbances, such as disk trenching, and increasingly heavy disturbance may reduce their ability to be recruited on a site.

The exposure of mineral soil would have provided a good germination medium for Carex aenea, which reproduces from seed and typically grows in disturbed areas (Moss and Packer 1983, MacKinnon *et al* 1992). Carex aenea seed may have come from nearby populations. Some Carex species have seed that survives for long periods of time in the soil (McGraw *et al* 1991). Thus some of the Carex aenea population may have a seed bank source that was exposed during mechanical site preparation. These results showing an increase of Carex aenea in disturbed areas agree with Eis (1981).

Equisetum arvense may have sprouted from deep roots that escaped removal by the mechanical treatments (Moss and Packer 1983). This sprouting from deep roots would account for the higher occurrence of horsetail on the disk trenched and ripper ploughed areas rather than on the bladed area. Mineral soil exposure would also have favoured horsetail establishment by providing a suitable environment for the germination of spores produced by nearby horsetail plants. Large numbers of horsetail sporophytes were noted on moist mineral soil on all three sites. These findings agree with Eis (1981) and Dymess *et al* (1988).

Polytricum commune would have arisen from spores, and the exposure of mineral soil would have favoured establishment and growth of these spores (Vitt *et al* 1988). Polytricum commune occurrence was very high on the non-treated control at Ante Creek (Table 3.5), however, this was due to a number of ruts that exposed mineral soil in this area that were not found in any of the other controls. The increase of Polytricum

commune on areas that have been mechanically disturbed does not agree with Dyrness *et al* (1988), however, Vitt *et al* (1988) note that Polytricum commune is often found growing on areas of disturbed mineral soil.

Populus spp. also increased on mechanically disturbed areas due to the exposure of mineral soil, which would have provided a suitable germination medium for Populus spp. seeds cast from nearby sources (Bell 1991). This increase due to mineral soil exposure is evident in the high occurrence of Populus spp. in the bladed areas (Table 3.5). As the seeds of aspen and balsam poplar are only viable for a few days to weeks (Bell 1991), it is unlikely that the seed bank was a source of propagules. Aspen also sprouted from residual roots that remained after the mechanical site preparation. Aspen was taller on the control areas because it was not removed from there by the mechanical treatments and thus had the benefit of two growing seasons after logging compared to only one growing season on the mechanically prepared areas. Due to the limited soil disturbance caused by the disk trencher, some of this two year old aspen would also have been retained in the disk trenched areas. This increase in aspen occurrence following logging agrees with Dyrness *et al* 1988, Eis 1981, and Norokorpi 1986).

Treatment Neutral Species

The next species group, the treatment neutral group, consisted of Epilobium angustifolium, fireweed, and Rubus pubescens, dewberry. Both these species showed no significant differences in height, cover, and frequency between treated and control areas. Dewberry and fireweed are found in the understory of both the LBC 4 and 5 ecosystem associations (Corns and Annas 1986) so it is likely that some clones would have survived the harvesting and site preparation treatments. As fireweed and dewberry growth in the mechanically treated areas was equal to that in the control, a limited amount of regeneration must have occurred in the treated areas. However, as there was no net

increase in growth of these species following treatment, they were not considered as increasers.

Most of the fireweed plants observed sprouted from rhizomes; based upon the observation of plots in June, fireweed did not appear to seed into the exposed mineral soil to any great extent. This may have been because the mineral soil exposed on these sites was too dry and infertile for the seed to germinate and establish (Bell 1991). The limited rhizome spread by fireweed into treated areas may indicate that the microsites were too harsh for extensive rhizome colonization or that there were too few fireweed clones that survived the logging of the original stand to provide a consistent source of regeneration material. Competition and lack of mineral soil presumably prevented extensive expansion by fireweed in the control. The limited amount of fireweed growth following logging agrees with Norokorpi (1986) but not with Hamilton and Yearsely (1988).

Dewberry has a small and transient seed bank (Whitney 1986). However, dewberry stands are long lived, although slow growing (Whitney 1986). Dewberry plants that survived logging, plus a limited amount of seed from the soil, would have provided regeneration material. The limited occurrence of dewberry on all four treatments would have been due to a limited amount of regeneration material present, the slow growing nature of dewberry, and the harshness of the microsites created as dewberry is favoured by shaded and moist areas (Whitney 1986).

Decreaser Species

The final group are species that generally decreased in abundance and height with mechanical site preparation. Most of these are understory species found in the LBC 4 and 5 (Corns and Annas 1986) so it is likely that some propagules would have been present on the sites following treatment. The general trend with these species was blading and

ripper ploughing caused a large reduction in cover and height while disk trenching reduced cover and height the least, or not at all, compared to the control.

Aralia nudicaulis, Petasites palmatus, Cornus canadensis, Mitella nuda, Mertensia paniculata, Pleurozium schreberi, and Ptilia crista-castrensis are all understory species. These species are adapted to the relatively moist, low light levels of the understory. When the canopy is removed, the full light and drier conditions reduce the vigour of these species. Therefore, they cannot compete well with invading species and they lose cover because the invading species are better adapted to the new conditions. Most of these species reproduce vegetatively (Moss and Packer 1983) and mechanical site preparation would have uprooted and removed the rootstocks, stolons, and rhizomes by which these species reproduce. These results agree with Dyrness (1973), Dyrness *et al* (1988), Eis (1981) and Hamilton and Yearsley (1988).

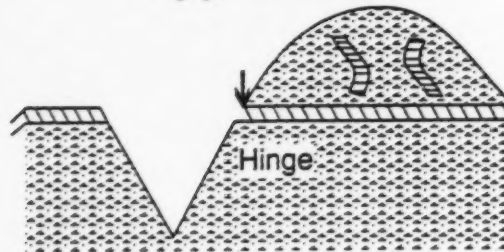
Rosa acicularis and Viburnum edule are also included among the group of species that decreased in cover and height with mechanical site preparation. Both prickly rose and mooseberry can be understory species in this area (Corns and Annas 1986), and it is probable that the disturbance caused by logging encouraged an increase in cover of these species in the growing season following logging, in the year before the mechanical site preparation was carried out. This would certainly account for the greater growth of these species in the control areas. Areas that were mechanically treated had a decrease in the occurrence and cover of these of these woody species due to a physical removal of the plants during the treatment. The one year following this removal would have given little opportunity for vegetative reproduction. Also, removal of soil containing buried seeds and harsh conditions of exposed microsites may have prevented extensive seeding in of these species (Bell 1991). These results agree with those of Eis (1981) and Hamilton and Yearsley (1988).

Rubus idaeus, also a decreaser, tended to have a lower occurrence as the severity of the mechanical treatments increased. The mechanism of raspberry colonization and removal during treatment was much the same as that described above for prickly rose and mooseberry. The main difference is that occurrence of raspberry was the same in the control and the disk trench. This may have occurred because the raspberry has a better ability to colonize adjacent, minor disturbances, such as shallow trenches, by rhizomes and root suckering (Whitney 1982), than mooseberry and prickly rose. Raspberry also has a large and persistent seed bank (Whitney 1986). Removal of the upper soil layers in the ripper plough and blade may have removed this seed. The possible presence of more seed and better growing conditions may account for greater raspberry growth in the disk trench. These results agree with those of Dyrness *et al* (1988).

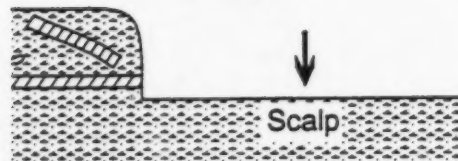
In the first year following mechanical site preparation, Calamagrostis canadensis was also reduced in cover and height. Bluejoint can survive in both understory and open environments (Corns and Annas 1986). Regeneration propagules could potentially include seed cast from nearby populations, rhizomes, and the seed bank (Conn 1990). After logging, and again, before the mechanical treatments, the residual bluejoint plants would have expanded on the sites, probably by rhizome extension but also possibly by seed in patches of exposed mineral soil. This expansion would partially account for the higher cover in the control areas. Mechanical treatments would have physically removed bluejoint plants and disrupted the root and rhizome systems of those not actually removed. Microsites in the mechanically treated areas may have been too warm for the extensive colonization of bluejoint by seed (Hogenbirk and Wein 1992). However, it was observed that when bluejoint did colonize mineral soil microsites, it did so via rhizome extension from adjacent, intact sods rather than by seed. Drainage and thus drying of the soil in the mechanical treatments, by creation of trenches and depressions and exposing the mineral soil, may have weakened residual bluejoint plants (Hogenbirk and Wein 1991) and

prevented more extensive rhizome growth. These results are contrary to those of Eis (1981), Dymess *et al* (1988), and Norokorpi (1986) which indicated that bluejoint extensively colonizes mechanically site prepared areas.

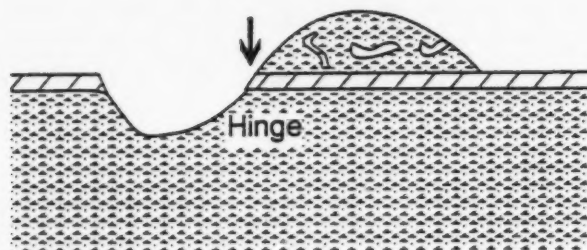
Ripper Plow



Blade



Disk Trench



Key

-  Mineral soil
-  Forest floor
-  Microsite used

Figure 3.1 Location of Microsites on Mechanical Treatments.

Table 3.1 Cover (percent) of Mineral Soil and Vegetation on Mechanically Site Prepared Areas in Northwestern Alberta (Mean and Standard Error)

Variable	Treatment	Means and Standard Errors by Location			
		Judy Creek	Fox Creek	Ante Creek	Combined
		Mean, SE	Mean, SE	Mean, SE	Mean, SE
Mineral Soil	Disk Trench	44.9, 8.3	62.0, 4.9	78.0, 3.3	63.2b, 4.1
	Ripper Plough	53.0, 3.4	87.4, 2.6	91.5, 1.8	77.3a, 3.9
	Blade	56.1, 7.0	94.8, 1.5	98.6, 0.5	83.4a, 4.7
	Control	0.00, 0.00	0.0, 0.0	14.7, 5.3	4.9c, 2.2
<i>Calamagrostis canadensis</i>	Disk Trench	2.2, 1.0	8.7, 3.1	0.0, 0.0	3.7b, 1.3
	Ripper Plough	3.4, 1.4	2.1, 2.1	0.0, 0.0	1.9b, 0.9
	Blade	1.2, 0.2	0.8, 0.4	0.0, 0.0	0.7b, 0.2
	Control	27.8, 4.4	36.5, 5.4	0.1, 0.1	21.5a, 3.9
<i>Carex aenea</i>	Disk Trench	1.8, 0.5	11.0, 2.4	8.0, 2.2	6.6a, 1.2
	Ripper Plough	1.5, 0.6	13.3, 2.8	1.5, 0.4	5.5a, 1.5
	Blade	0.6, 0.3	6.7, 2.1	0.2, 0.1	2.7b, 0.9
	Control	0.00, 0.00	0.1, 0.1	5.0, 0.5	1.8b, 0.5
<i>Epilobium angustifolium</i>	Disk Trench	3.6, 1.3	0.5, 0.3	0.0, 0.0	1.3a, 0.5
	Ripper Plough	2.8, 1.4	0.3, 0.1	0.0, 0.0	1.3a, 0.5
	Blade	0.8, 0.7	0.3, 0.1	0.0, 0.0	0.5a, 0.3
	Control	4.0, 1.8	0.0, 0.0	1.1, 0.6	1.7a, 0.7
<i>Equisetum arvense</i>	Disk Trench	2.6, 1.5	3.5, 1.1	1.2, 0.3	2.5a, 0.6
	Ripper Plough	2.2, 1.6	1.3, 0.4	0.7, 0.2	1.6ab, 0.5
	Blade	0.1, 0.1	1.0, 0.3	0.3, 0.3	0.6b, 0.2
	Control	0.00, 0.00	1.7, 0.6	1.5, 0.6	1.1b, 0.3
<i>Mertensia paniculata</i>	Disk Trench	1.2, 0.6	0.0, 0.0	*	0.6b, 0.4
	Ripper Plough	5.0, 0.9	0.0, 0.0	*	2.5b, 1.1
	Blade	2.3, 0.7	0.0, 0.0	*	1.1b, 0.4
	Control	10.8, 2.7	2.9, 0.6	*	6.9a, 1.7
<i>Rubus idaeus</i>	Disk Trench	1.1, 0.5	3.3, 0.9	0.0, 0.0	1.5b, 0.4
	Ripper Plough	2.6, 0.7	0.6, 0.3	0.0, 0.0	1.1b, 0.3
	Blade	3.2, 1.1	0.2, 0.1	0.0, 0.0	1.1b, 0.5
	Control	1.9, 0.9	8.5, 1.9	1.5, 0.6	4.0a, 1.0
<i>Populus tremuloides</i>	Disk Trench	3.7, 1.9	0.0, 0.0	*	1.8a, 1.1
	Ripper Plough	1.5, 0.8	0.0, 0.0	*	0.8a, 0.4
	Blade	1.8, 0.8	0.0, 0.0	*	0.9a, 0.4
	Control	5.6, 2.4	0.0, 0.0	*	2.8a, 1.4
<i>Aralia nudicaulis</i>	Disk Trench	0.7, 0.3	0.1, 0.9	*	0.4b, 0.2
	Ripper Plough	1.8, 0.8	0.0, 0.0	*	1.9b, 1.1
	Blade	0.8, 0.8	0.0, 0.0	*	0.4b, 0.2
	Control	9.9, 1.1	2.0, 0.9	*	6.0a, 1.2
<i>Viburnum edule</i>	Disk Trench	0.6, 0.2	*	*	0.6b, 0.2
	Ripper Plough	0.7, 0.5	*	*	0.7b, 0.5
	Blade	0.8, 0.6	*	*	0.8b, 0.6
	Control	5.2, 0.8	*	*	5.2a, 0.8

Note: Identical letters in the same column indicate no significant differences ($p < 0.05$) between treatments as determined by Scheffe's test.

Asterisks (*) indicate that the species was absent from the site and thus the site was not used in the combined means calculation.

Table 3.2 Height (cm) of Vegetation on Mechanically Site Prepared Areas
Areas in Northwestern Alberta (Mean and Standard Error)

Species	Treatment	Means and Standard Errors by Location			
		Judy Creek	Fox Creek	Ante Creek	Combined
		Mean, SE	Mean, SE	Mean, SE	Mean, SE
<i>Calamagrostis canadensis</i>	Disk Trench	24.6, 6.5	33.7, 5.3	0.6, 0.6	19.6b, 4.0
	Ripper Plough	26.3, 5.9	5.9, 5.9	2.5, 2.5	11.6b, 3.5
	Blade	26.7, 6.4	9.9, 4.9	0.0, 0.0	12.2b, 3.5
	Control	53.5, 3.7	56.6, 2.7	5.4, 5.4	38.8a, 5.4
<i>Carex aenea</i>	Disk Trench	20.9, 1.1	19.9, 1.4	17.1, 2.9	19.3a, 1.2
	Ripper Plough	10.8, 3.3	18.5, 1.8	6.5, 1.6	11.9b, 1.7
	Blade	10.5, 4.4	12.8, 2.4	2.0, 1.2	8.4bc, 1.9
	Control	0.0, 0.0	2.0, 2.0	14.6, 1.8	5.5c, 1.5
<i>Epilobium angustifolium</i>	Disk Trench	17.1, 5.8	4.4, 2.4	0.0, 0.0	6.8a, 2.5
	Ripper Plough	15.4, 7.2	1.1, 0.2	0.0, 0.0	6.5a, 2.8
	Blade	8.5, 6.3	0.8, 0.2	0.0, 0.0	3.1a, 2.2
	Control	18.2, 5.0	0.0, 0.0	5.1, 2.3	7.8a, 2.4
<i>Equisetum arvense</i>	Disk Trench	9.8, 5.0	6.9, 1.7	5.8, 1.9	7.5a, 1.8
	Ripper Plough	16.1, 6.0	4.7, 1.4	2.1, 0.7	8.0a, 2.3
	Blade	3.1, 2.4	6.3, 2.2	0.9, 0.9	3.4a, 1.2
	Control	0.0, 0.0	13.3, 3.8	10.5, 3.2	7.9a, 2.0
<i>Mertensia paniculata</i>	Disk Trench	3.8, 1.8	0.0, 0.0	*	1.9b, 1.0
	Ripper Plough	8.8, 1.6	0.0, 0.0	*	4.4b, 0.9
	Blade	5.9, 2.2	0.0, 0.0	*	3.0b, 1.2
	Control	14.2, 1.8	15.8, 4.4	*	15.0a, 2.3
<i>Rubus idaeus</i>	Disk Trench	5.8, 1.9	5.9, 1.1	0.1, 0.1	4.0a, 0.8
	Ripper Plough	8.7, 2.4	1.4, 0.6	0.5, 0.5	4.3a, 1.3
	Blade	15.6, 5.0	0.9, 0.4	0.0, 0.0	5.5a, 2.2a
	Control	9.9, 3.8	12.6, 2.9	3.9, 1.5	20.0a, 10.5a
<i>Populus tremuloides</i>	Disk Trench	23.9, 9.6	0.5, 0.5	*	10.8ab, 5.4
	Ripper Plough	9.9, 5.0	0.0, 0.0	*	5.0b, 2.8
	Blade	9.1, 2.4	0.0, 0.0	*	4.9b, 1.7
	Control	43.9, 16.8	0.0, 0.0	*	21.9a, 9.9
<i>Aralia nudicaulis</i>	Disk Trench	4.6, 1.2	2.9, 1.9	*	3.8b, 1.1
	Ripper Plough	12.8, 1.4	0.0, 0.0	*	6.4ab, 2.9
	Blade	0.3, 0.3	0.0, 0.0	*	0.1b, 0.1
	Control	17.3, 0.8	7.0, 2.8	*	12.2a, 1.9
<i>Viburnum edule</i>	Disk Trench	6.0, 2.0	*	*	6.0b, 2.0
	Ripper Plough	6.6, 3.3	*	*	6.6b, 3.3
	Blade	3.0, 2.0	*	*	3.0b, 2.0b
	Control	20.4, 3.2	*	*	20.4a, 3.2

Note: Identical letters in the same column indicate no significant differences ($p < 0.05$) between treatments as determined by Scheffe's test.

Asterisks (*) indicate that the species was absent from the site and thus the site was not used in the combined means calculation.

Table 3.3 Analysis of Variance for Mineral Soil and
Vegetation Cover on Mechanically Prepared Sites in Northwestern Alberta

Variable	Source	Df	SS	MS	Test F	P	Significance
Mineral Soil	Block	2	16309.78	8154.89	44.23	0.0001	***
	Treatment	3	92114.27	30704.76	254.29	0.0001	***
	Subplot Error	29	3469.09	120.75			
<i>Calamagrostis canadensis</i>	Block	2	2428.4	1214.2	12.36	0.0001	***
	Treatment	3	6861.27	2287.09	50.90	0.0001	***
	Subplot Error	28	1258.12	44.93			
<i>Carex aenea</i>	Block	2	689.50	344.75	14.63	0.0001	***
	Treatment	3	368.92	122.97	8.23	0.0004	***
	Subplot Error	28	419.13	14.97			
<i>Equisetum arvense</i>	Block	2	15.11	7.56	1.53	0.2242	NS
	Treatment	3	47.52	15.84	4.37	0.0121	**
	Subplot Error	28	101.58	3.63			
<i>Mertensia paniculata</i>	Block	1	111.04	111.04	5.63	0.024	**
	Treatment	3	390.24	130.08	11.47	0.0001	***
	Subplot Error	28	317.49	11.34			
<i>Rubus idaeus</i>	Block	2	117.62	58.81	7.018	0.0018	***
	Treatment	3	138.92	46.31	8.18	0.0005	***
	Subplot Error	28	158.54	5.66			
<i>Aralia nudicaulis</i>	Block	1	53.66	53.66	3.62	0.0664	*
	Treatment	3	331.96	110.65	18.48	0.0001	***
	Subplot Error	28	167.69	5.99			
<i>Populus tremuloides</i>	Block	1	155.00	155.00	13.91	0.0008	***
	Treatment	3	42.59	14.20	1.317	0.2887	NS
	Subplot Error	28	301.84	10.78			
<i>Viburnum edule</i>	Treatment	3	121.25	40.42	15.31	0.0001	***
	Subplot Error	21	3469.09	120.75			
<i>Epilobium angustifolium</i>	Block	2	128.84	64.42	12.39	0.0001	***
	Treatment	3	17.35	5.78	1.17	0.3389	NS
	Subplot Error	28	138.32	4.94			

Note: Significance level is indicated by * for 0.1; ** for 0.05; *** for 0.01; and NS for not significant. Block is a test for differences among sites. Treatments are listed in Tables 3.3 and 3.2.

Table 3.4 Analysis of Variance for Height of Vegetation on Mechanically Prepared Sites in Northwestern Alberta

Variable	Source	Df	SS	MS	Test F	P	Significance
<i>Calamagrostis canadensis</i>	Block	2	16982.46	8491.23	35.86	0.0001	***
	Treatment	3	11632.55	3877.52	16.20	0.0001	***
	Subplot Error	28	6700.54	239.31			
<i>Carex aenea</i>	Block	2	195.43	97.71	1.467	0.2385	NS
	Treatment	3	2541.09	847.03	17.85	0.0001	***
	Subplot Error	28	1328.49	47.45			
<i>Equisetum arvense</i>	Block	2	130.37	65.19	0.709	0.4961	NS
	Treatment	3	350.22	116.74	1.72	0.1855	NS
	Subplot Error	28	101.58	3.63			
<i>Mertensia paniculata</i>	Block	1	1.32	1.32	0.013	0.909	NS
	Treatment	3	1379.88	459.96	79.81	0.0034	***
	Subplot Error	28	2234.82	79.82			
<i>Rubus idaeus</i>	Block	2	1449.73	724.86	1.003	0.3727	NS
	Treatment	3	4311.24	1437.08	2.19	0.1114	NS
	Subplot Error	28	18373.04	656.18			
<i>Aralia nudicaulis</i>	Block	1	12.51	12.51	0.127	0.7238	NS
	Treatment	3	659.42	219.80	3.23	0.0374	**
	Subplot Error	28	1905.93	68.07			
<i>Populus tremuloides</i>	Block	1	7072.81	7072.81	15.13	0.0005	***
	Treatment	3	3078.42	1026.14	2.54	0.0768	*
	Subplot Error	28	301.84	10.78			
<i>Viburnum edule</i>	Treatment	3	1305.50	436.50	7.54	0.0013	***
	Subplot Error	21	1215.88	57.9			
<i>Epilobium angustifolium</i>	Block	2	3780.48	1890.24	16.48	0.0001	***
	Treatment	3	297.55	99.18	1.13	0.3536	NS
	Subplot Error	28	2456.44	87.73			

Note: Significance level is indicated by * for 0.1; ** for 0.05; *** for 0.01; and NS for not significant. Block is a test for differences among sites. Treatments are listed in Tables 3.3 and 3.2.

Table 3.5 Percent of Quadrats in Which Species Occurred in Mechanically Site Prepared Areas in Northwestern Alberta

Species	Treatment	Percent Occurrence by Location			
		Judy Creek	Fox Creek	Ante Creek	Combined
		%	%	%	%
<i>Calamagrostis canadensis</i>	Disk Trench	32.50	45.00	2.50	26.67b
	Ripper Plough	35.00	5.00	2.50	14.17c
	Blade	30.00	10.00	0.00	13.33c
	Control	85.00	90.00	2.50	59.17a
<i>Carex aenea</i>	Disk Trench	42.50	77.50	57.50	59.17a
	Ripper Plough	27.50	80.00	47.50	51.67b
	Blade	20.00	60.00	7.50	29.17c
	Control	0.00	2.50	50.00	17.50d
<i>Equisetum arvense</i>	Disk Trench	25.00	47.50	37.50	36.67a
	Ripper Plough	20.00	45.00	35.00	33.33a
	Blade	7.50	37.50	5.00	16.67b
	Control	0.00	35.00	20.00	18.33b
<i>Epilobium angustifolium</i>	Disk Trench	27.50	10.00	0.00	12.50a
	Ripper Plough	15.00	30.00	0.00	15.00a
	Blade	5.00	27.50	0.00	11.17a
	Control	25.00	0.00	15.00	13.33a
<i>Aralia nudicaulis</i>	Disk Trench	20.00	5.00	*	12.5b
	Ripper Plough	32.50	0.00	*	16.25b
	Blade	2.50	0.00	*	0.00c
	Control	67.50	12.50	*	33.75a
<i>Mertensia paniculata</i>	Disk Trench	12.50	0.00	*	6.25b
	Ripper Plough	27.50	0.00	*	13.75b
	Blade	17.50	0.00	*	8.75b
	Control	62.50	17.50	*	27.50a
<i>Rubus idaeus</i>	Disk Trench	22.50	47.50	2.50	24.17a
	Ripper Plough	37.50	20.00	2.50	20.00b
	Blade	20.00	12.50	0.00	10.83c
	Control	12.50	55.00	15.00	27.50a
<i>Populus spp.</i>	Disk Trench	40.00	22.50	20.00	27.50a
	Ripper Plough	32.50	0.00	12.50	15.00b
	Blade	37.50	5.00	22.50	21.67ab
	Control	20.00	0.00	2.50	7.50c
<i>Viburnum edule</i>	Disk Trench	20.00	0.00	*	20.00b
	Ripper Plough	12.50	0.00	*	12.50b
	Blade	5.00	0.00	*	5.00c
	Control	50.00	0.00	*	50.00a

Note: Identical letters in the same column indicate no significant differences ($p < 0.05$) as given by a chi-square and a Z test.

Asterisks (*) indicate that species was absent from the site and thus the site was not used in the calculation of combined mean.

Table II.5 (continued)

Species	Treatment	Percent Occurrence by Location			
		Judy Creek	Fox Creek	Ante Creek	Combined
		%	%	%	%
<i>Rosa acicularis</i>	Disk Trench	22.50	0.00	0.00	7.50ab
	Ripper Plough	7.50	2.50	0.00	3.33bc
	Blade	2.50	0.00	0.00	0.80c
	Control	10.00	12.50	5.00	9.17a
<i>Petasites palmatus</i>	Disk Trench	15.00	7.50	2.50	8.33a
	Ripper Plough	5.00	2.50	0.00	2.50b
	Blade	7.50	0.00	0.00	2.50b
	Control	12.50	2.50	12.50	9.17a
<i>Cornus canadensis</i>	Disk Trench	30.00	25.00	2.50	19.17b
	Ripper Plough	12.50	2.50	0.00	5.00c
	Blade	15.00	0.00	0.00	5.00c
	Control	47.50	30.00	25.00	34.17a
<i>Mitella nuda</i>	Disk Trench	5.00	10.00	2.50	7.50b
	Ripper Plough	2.50	2.50	0.00	2.50b
	Blade	0.00	0.00	0.00	0.00b
	Control	35.00	32.50	25.00	33.75a
<i>Rubus pubescens</i>	Disk Trench	52.50	10.00	0.00	20.8a
	Ripper Plough	20.00	5.00	2.50	9.17a
	Blade	52.50	2.50	0.00	18.33a
	Control	47.50	22.50	12.50	27.50a
<i>Pleurozium schreberi</i>	Disk Trench	2.50	7.50	12.50	7.50b
	Ripper Plough	2.50	0.00	7.50	3.33b
	Blade	0.00	0.00	0.00	0.00c
	Control	42.50	30.00	7.50	26.67a
<i>Ptilia crista-castrensis</i>	Disk Trench	15.00	2.50	10.00	9.17a
	Ripper Plough	2.50	2.50	2.50	3.33bc
	Blade	0.00	0.00	0.00	0.00c
	Control	5.00	32.50	2.50	13.33a
<i>Polytrichum commune</i>	Disk Trench	30.00	55.00	42.50	42.50a
	Ripper Plough	0.00	15.00	17.50	10.83c
	Blade	0.00	12.50	0.00	4.17d
	Control	0.00	7.50	50.00	19.17b

Note: Identical letters in the same column indicate no significant differences ($p < 0.05$) as given by a chi-square and a Z test.

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4. CONCLUSION

Two experiments were conducted to investigate the ability of Calamagrostis canadensis, and other species of vegetation, to colonize and grow on mechanically site prepared clearcuts in northwestern Alberta.

Experiment One

In the first experiment, the ability of bluejoint rhizomes to sprout and grow in different microsites created by disk trenching, ripper ploughing, blading, and non-treated controls was investigated. It was found that:

- the amount of new rhizome mass grown was greatest in the disk trench microsite with no differences among the other three treatments
- the amount of new shoot mass was greatest in the disk trench microsite with no differences among the other three treatments
- shoot heights were greatest in the disk trench, followed by the ripper plough with no difference between the blade and control
- shoot number was highest in the disk trench with no differences among the other three treatments
- the number of new rhizomes grown was highest in the disk trench and the ripper plough followed by the blade and the control
- the total length of new rhizome grown was greatest in the disk trench and the ripper plough followed by the blade and the control
- the number of rhizome growing tips was greatest on the disk trench with no differences between the other three treatments
- the greatest number of ramets were found in the disk trench followed by the blade, the ripper plough, and the control

-no significant difference for maximum rhizome extension were found among the four treatments

These results suggest that the disk trenched microsite supported the best growth of bluejoint. Secondly, the ripper plough was able to support better growth than either the blade or the control. The ability of the disk trench microsite to support this superior growth is most likely due to superior growing conditions found there. Therefore, use of disk trenching for control of bluejoint is not suggested. The greater shoot growth and total rhizome mass found in the disk trench suggest that there is more photosynthate and carbohydrate storage in bluejoint plants in the disk trenched areas. This greater amount of carbohydrate reserve plus greater number of growing tips suggests that rate of bluejoint colonization of the sites will be even greater, compared to the other treatments, in subsequent growing seasons. However, the improved growing conditions in the disk trench would improve tree growth. Therefore, disk trenching coupled with another vegetation control measure, such as herbicide or grazing by domestic stock, may give good result in the regeneration of white spruce plantations.

Experiment Two

In the second experiment, the cover, occurrence, and height of bluejoint, in addition to other species of vegetation, plus the amount of mineral soil exposed by disk trenching, ripper ploughing, blading, and non-treated controls was measured. It was found that three groups of species could be delineated:

1. Species that increased their cover, occurrence, and height with mechanical site preparation.
2. Species which were treatment neutral.

3. Species which decreased their cover, occurrence, and height with mechanical site preparation.

A. The increaser or colonizer species included Carex aenea, Equisetum arvense, Populus tremuloides, and Polytrichum commune; these species tended to have the greatest cover, occurrence, and height on the disk trench, followed by the ripper plough, the blade, and finally the control.

- these species increased their cover with mechanical site preparation due to the increased exposure of mineral soil which likely allowed for establishment from seed and spores and by vigorously sprouting from residual rootstocks

B. The treatment neutral group included Epilobium angustifolium and Rubus pubescens, species which are found in the understory of the intact forest.

- the mineral soil microsites provided by mechanical site preparation were too severe for fireweed to extensively establish by either seed or rhizome, although some colonization did occur

- dewberry spread by stolon growth, with extensive growth probably limited by dry, exposed conditions in mechanically treated microsites and competition in the control

C. The decreaser species included Calamagrostis canadensis, Aralia nudicaulis, Mertensia paniculata, Rubus idaeus, Viburnum edule, Rosa acicularis, Petasites palmatus, Cornus canadensis, Mitella nuda, Pleurozium schreberi, and Ptilia crista-castrensis, which are all understory species in the intact forest. These species tended to have their greatest cover, occurrence, and height on the control followed by the disk trench, the ripper plough, and finally the blade.

- the decreaser species tend to be clonal species and their roots, rhizomes, and crowns were removed by the mechanical treatments

- removal of the top soil layers likely removed the seeds of seed banking species

-dry, exposed conditions in the mechanically prepared areas provided poor growing conditions for the mosses

The best recruitment and growth of the invader group was in the disk trench treatment. Excluding the control, the best growth of the decreaser group was also in the disk trenched areas. This superior growth in the disk trench is probably due to better growing conditions provided in the microsite there and because fewer plants were actually uprooted and removed during treatment. With the exception of aspen, the low stature of the invading species suggests that they probably will not compete heavily for light with the crop trees, although they may compete for soil nutrients and possibly increase the risk of summer frost. The growth of residual understory species is, out of the three mechanical treatments, best in the disk trenched areas. Therefore, the recovery and reestablishment of pre-disturbance plant communities is, likely, best facilitated in the disk trenched areas.

What is unusual about these results are that bluejoint did not quickly and extensively colonize mechanically treated areas, as suggested by many researchers, and, where colonization did occur, it was via rhizomes rather than by seed as suggested by Macdonald and Lieffers (1991). The former underscores the fact that these are only first year results and very likely do not reflect what long term conditions might be. Consequently, the results, particularly regarding bluejoint, should be viewed with caution. The latter is partial confirmation of the theory that bluejoint colonizes mineral soil first by rhizome extension and then by subsequent seed cast, once the plants are established (Herring as cited by Haeussler *et al.*, 1991). Another possible mechanism for subsequent bluejoint colonization and dominance on the sites is that establishment of the colonizing species mentioned above modifies microsites and makes them more hospitable for the germination and establishment of bluejoint.

In forestry, the aim is to reestablish a crop of trees as soon as possible on a site after it has been logged. This often involves reducing the time spent in early seral stages; in

essence this is a short-circuiting of succession. In order to do this, it is necessary to provide some sort of competitive advantage to the crop trees. By providing such an advantage, we can grow crop trees and, concurrently, maintain a cover of other species of plants. It is generally recognized that to maintain a healthy, productive ecosystem in the long run, we must maintain both crop trees and non-crop species of plants. To eradicate every non-crop plant species by mechanical means in one treatment would require such a heavy treatment that serious losses in site quality would result. Such is the case with the blading on the Fox and Ante Creek sites, which controlled bluejoint and other species the best but in doing so, soil was removed down to the B and C horizons.

In order to achieve the goals outlined above, disk trenching is the best of the three mechanical treatments examined. The growth of most species, including the notoriously competitive bluejoint, on the disk trench is indicative of the superior growing conditions provided in the microsite in this treatment. Such good growing conditions would enhance the establishment and growth of crop trees, in addition to the growth of other species of vegetation. By retaining more understory species, the impact of the treatment on sites is reduced and the reestablishment of seral plant communities of greater similarity to those in the original undisturbed stand is likely promoted more than in either the blade or the ripper plough. However, disk trenching alone is not enough to establish a crop of trees, due to the growth of competitive species. Disk trenching should be combined with some other form of vegetation control, such as herbicides or prescribed fire. Such a combination would enhance the competitive advantage of the crop trees by providing a good growing environment for crop trees and retard the growth of potentially competitive species plus reduce their ability to take advantage of the enhanced growing conditions.

Given public rejection of severe site modifying treatment and the reduction in site quality often associated with such treatments, a lighter treatment, more in tune with ecosystem processes rather than engineering is required. Vegetation management research

should be directed towards the modifying target species' ability to compete and enhancing the competitive ability of crop species instead of wholesale removal of the target species.

Specific projects might include:

- more investigation of the life-cycles of target species and their potential weak point (Wagner and Zasada 1991)
- techniques for replacing heavy competitors with species that compete less with crop trees, such as low growing agronomic species
- development of methods for managing mixed wood rather than pure conifer stands
- the development of alternative silvicultural systems, based on partial cutting, that retain part of the tree canopy during regeneration of the crop species and deny competitors the advantage of full light conditions
- investigation of the long-term effects of mechanical site preparation on site quality and plant communities
- investigation of prescribed burning as a vegetation control method in the boreal forest
- investigation of the use of grazing by domestic stock to control competitor species

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